



Remote Sensing of Urban Heat: Detection, Trends, and Societal Vulnerability



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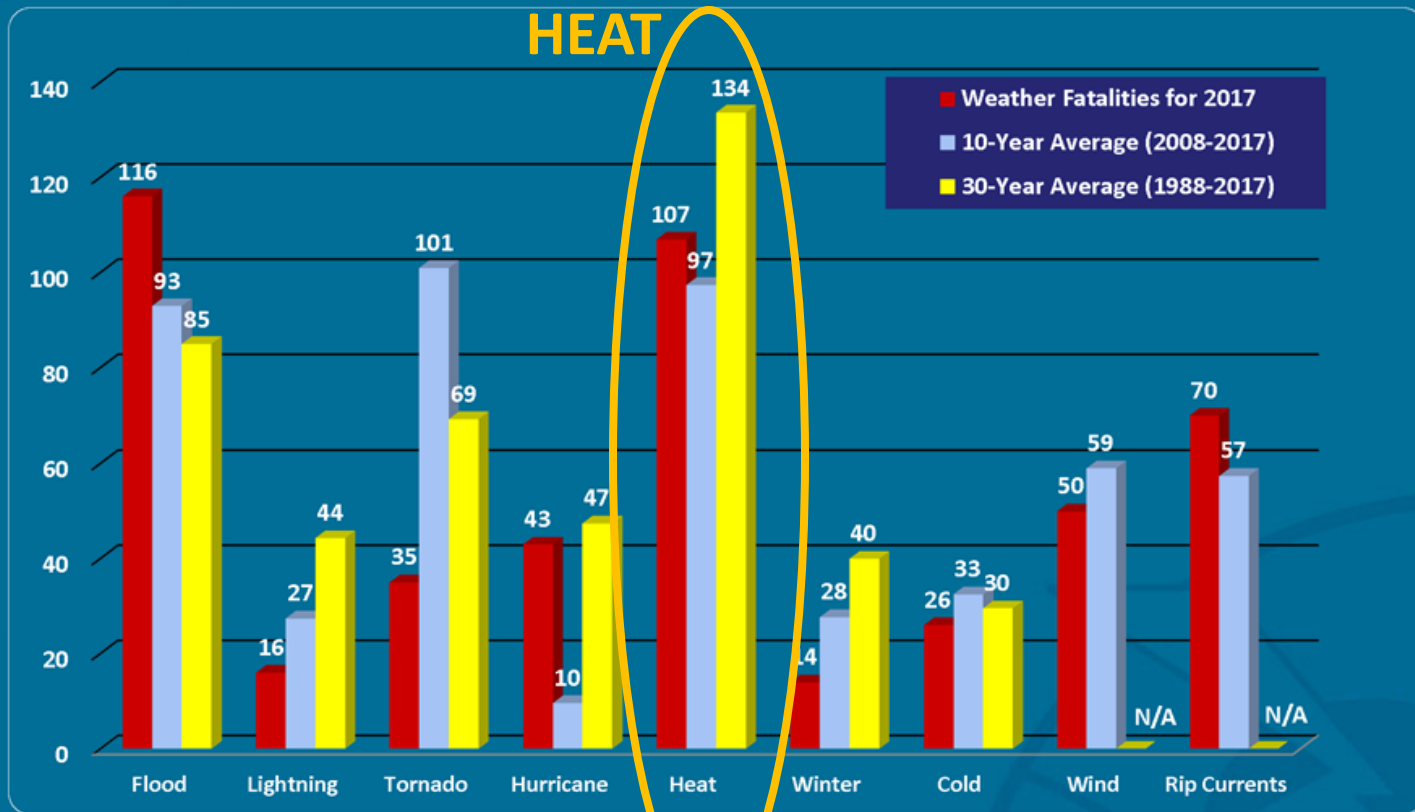
University of California Santa Barbara

Decadal Survey Relevance

- ***H-4d.*** Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of and response to hazards. This is tightly linked to H2a, H2b, H4a, H4b, H4, and H4d.
- ***tq4:*** How does urbanization affect the local, regional and global environment? Can we characterize this effect to help mitigate its impact on human health and welfare?

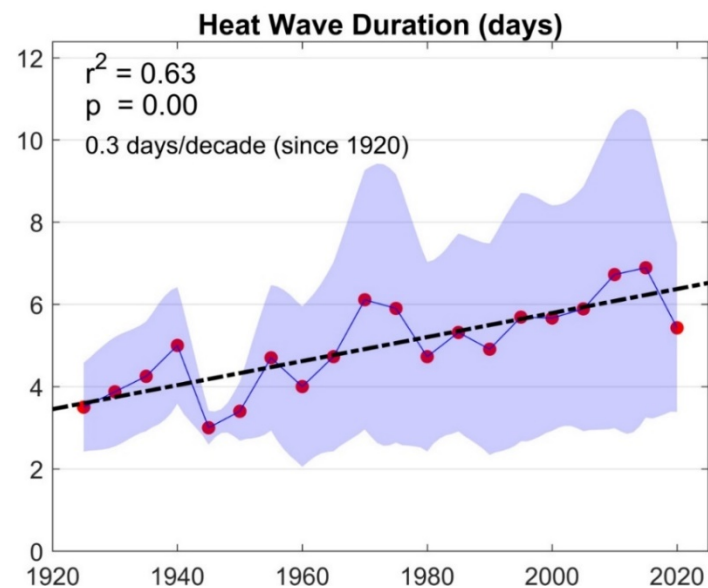
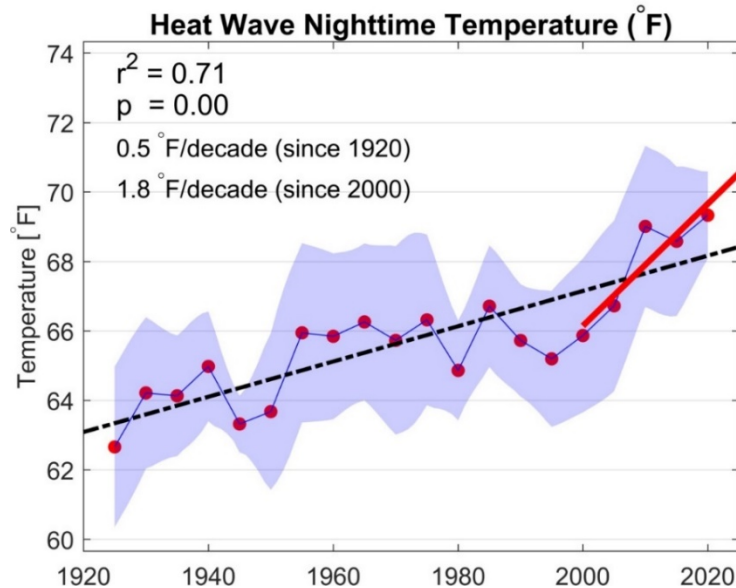
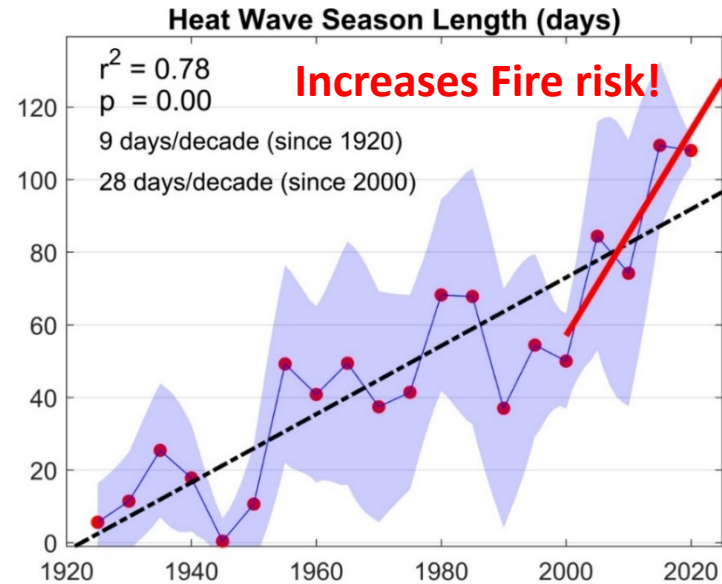
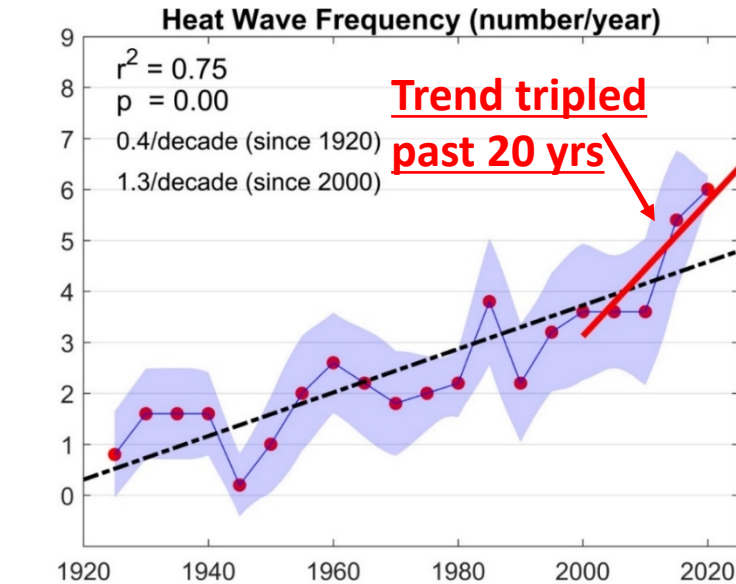


Weather Fatalities 2017



Source: <http://www.nws.noaa.gov/om/hazstats.shtml>

Los Angeles Heat Wave Trends



**Human
health
impacts
(Morbidity,
Mortality)**

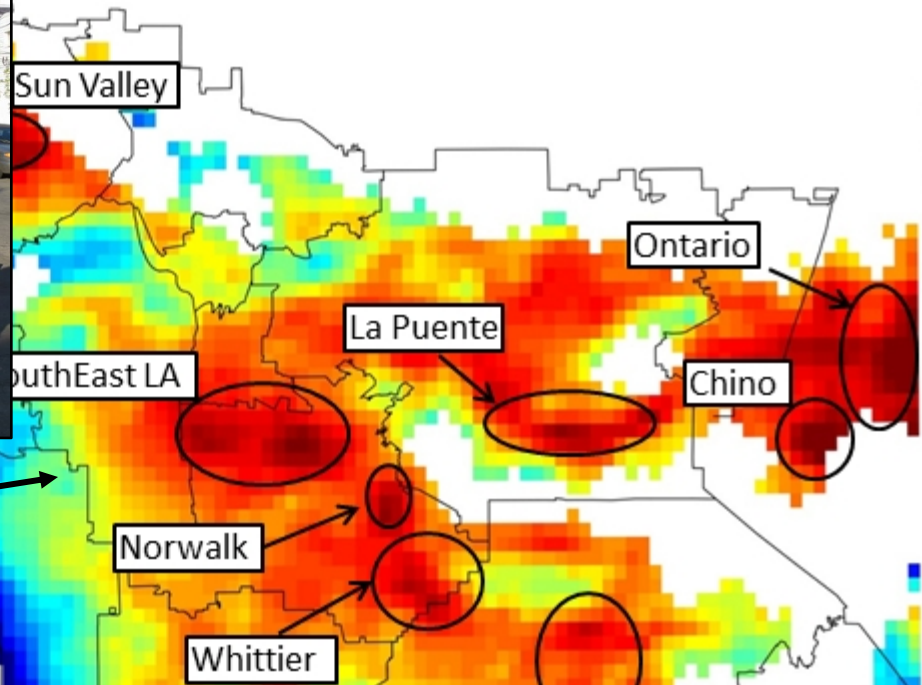
Daytime MYD21 LST Heat Wave Climatology (2002-2018)

[°C]

34.4° N



~15 C gradient in temperature due to onshore flow cooling



Cool Roofs



Cool Roads

10 °C cooler

33.5° N

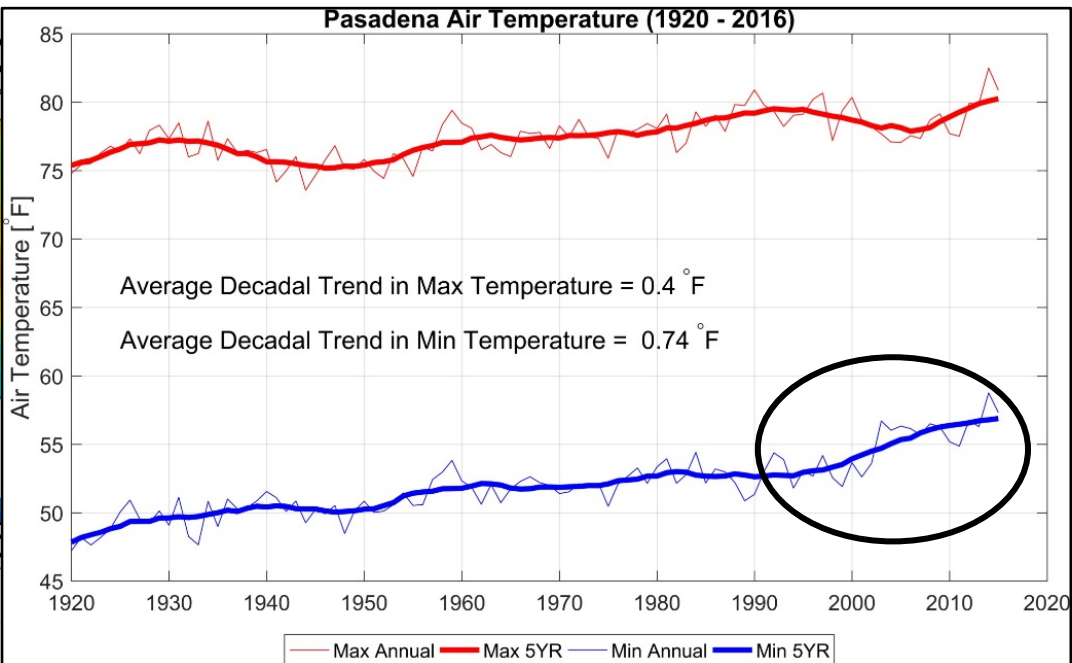
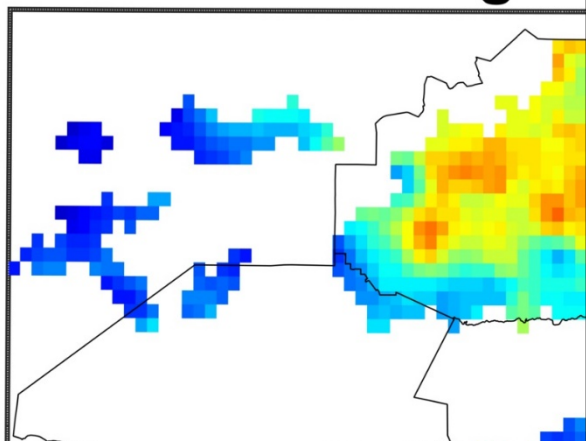
119.0° W

Hulley et al. 2018

117.6° W

34.4° N

Annual average of



18
16
14
12
10

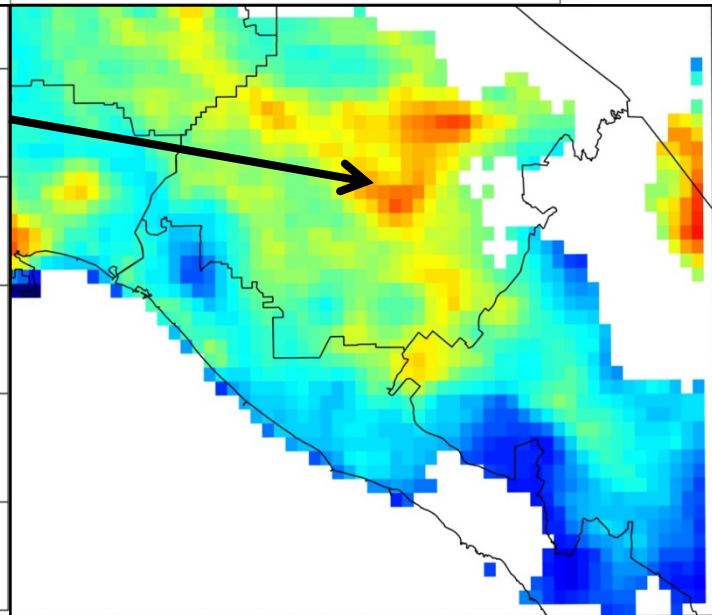
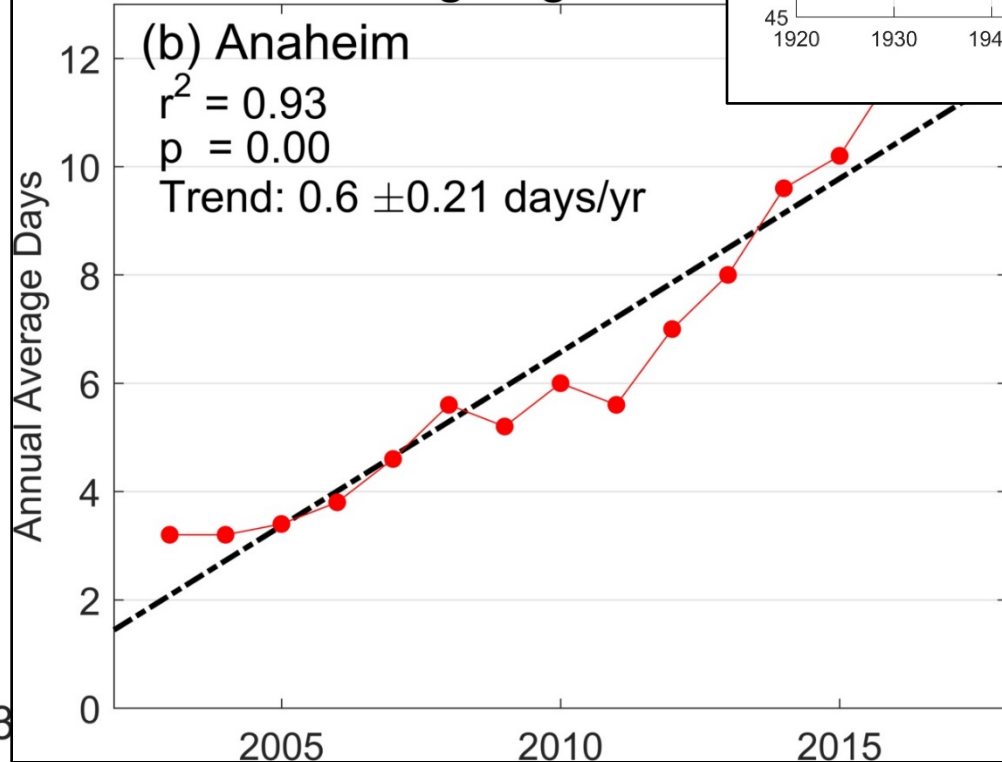
Annual average nighttime cloud cover

(b) Anaheim

$$r^2 = 0.93$$

$$p = 0.00$$

Trend: 0.6 ± 0.21 days/yr



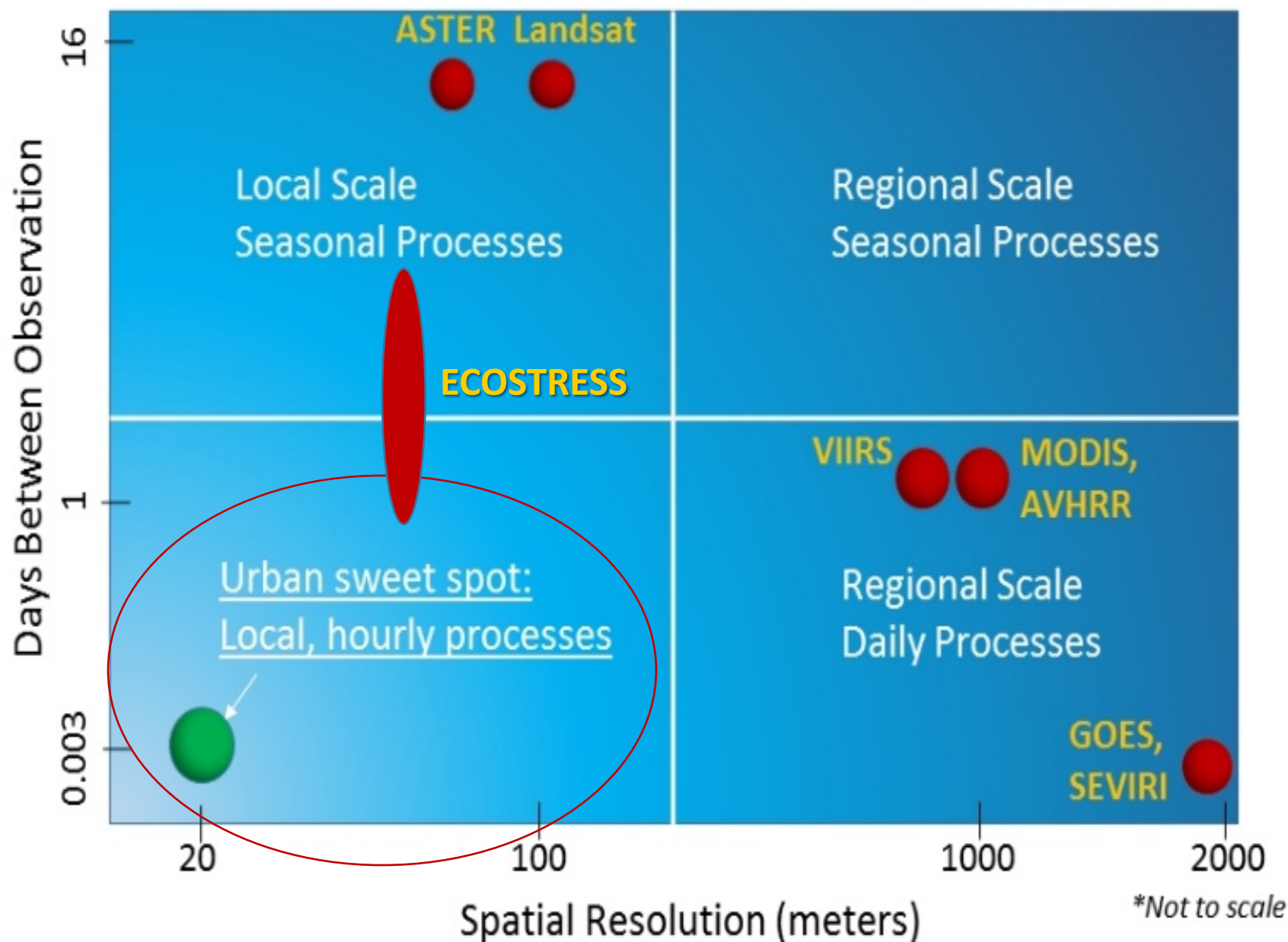
8
6
4
2
0

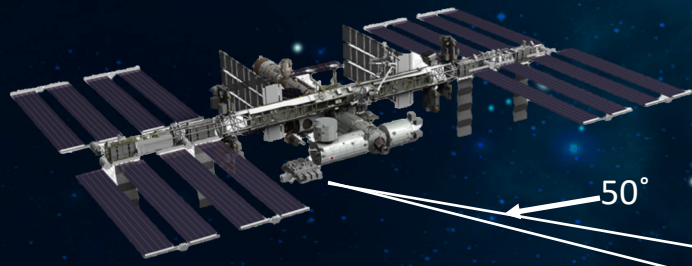
Hulley et al. 2018

119.0° W

117.6° W

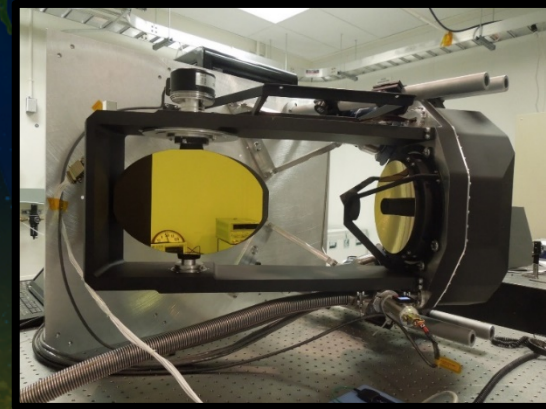
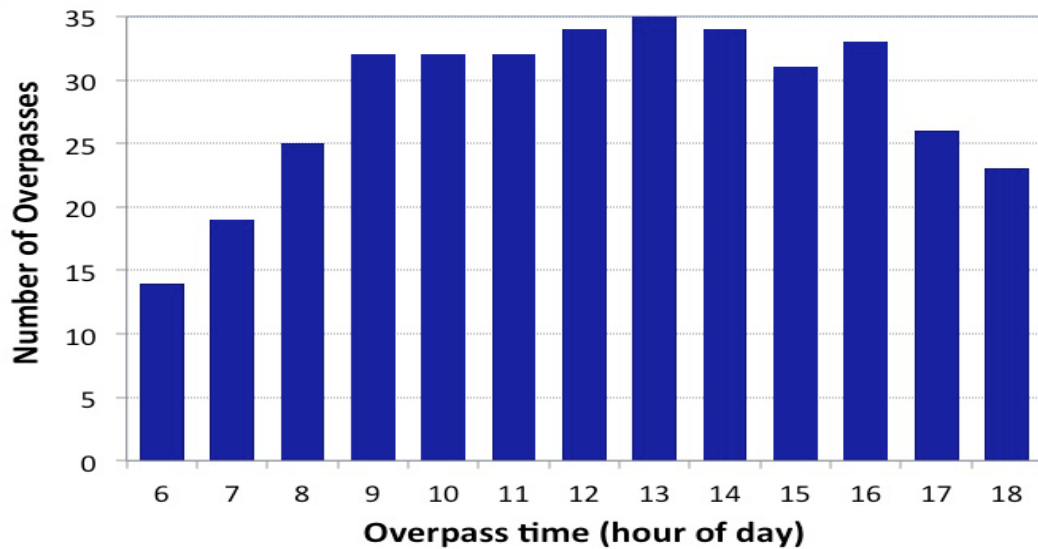
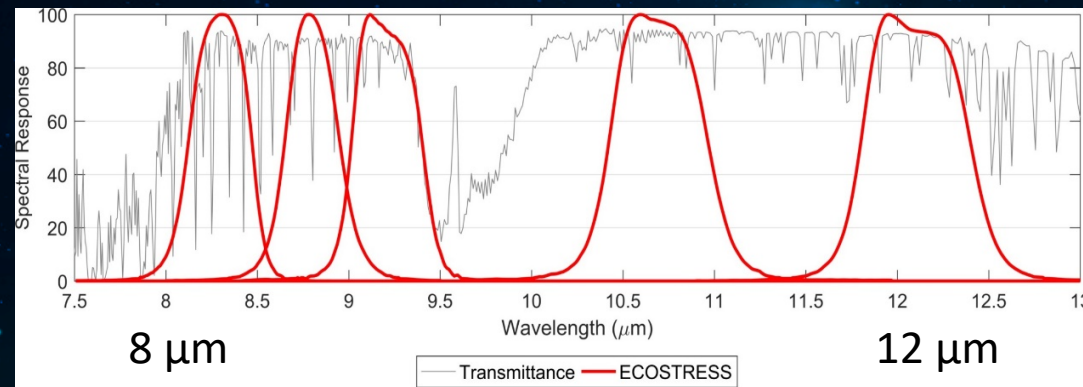
Revisit Time vs Spatial Resolution of current TIR sensors





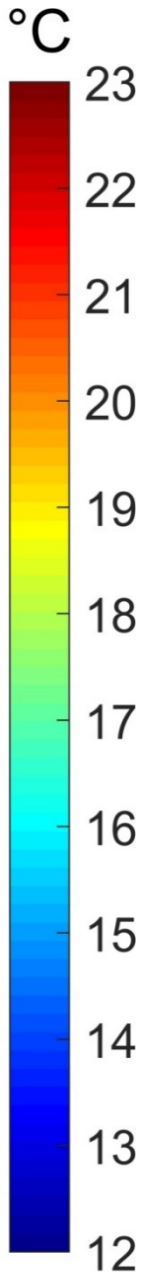
50°

400 km
(70 m)



ECOSTRESS LST, 22 July 2018, 04:07 PST

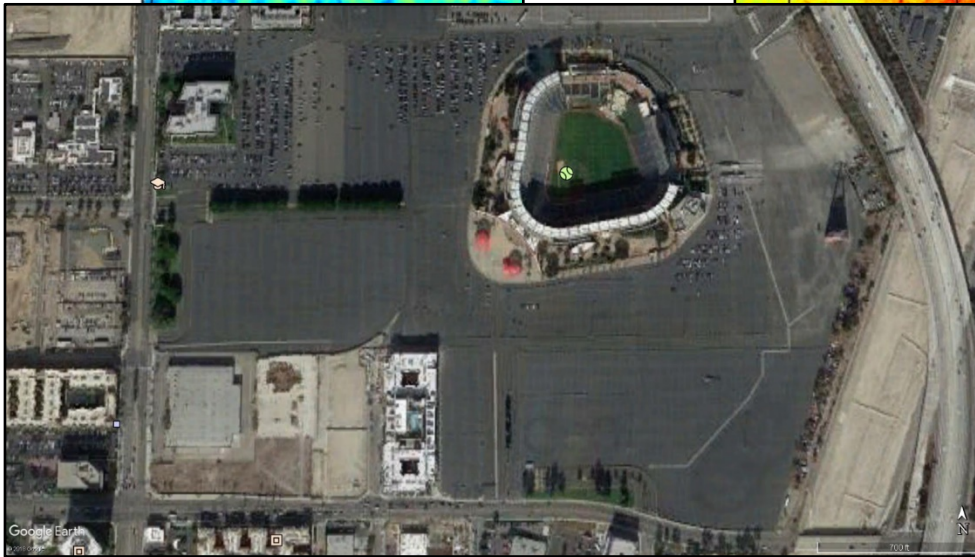
34.4° N



Burbank
Airport

Freeways

LA Angels
Parking lot

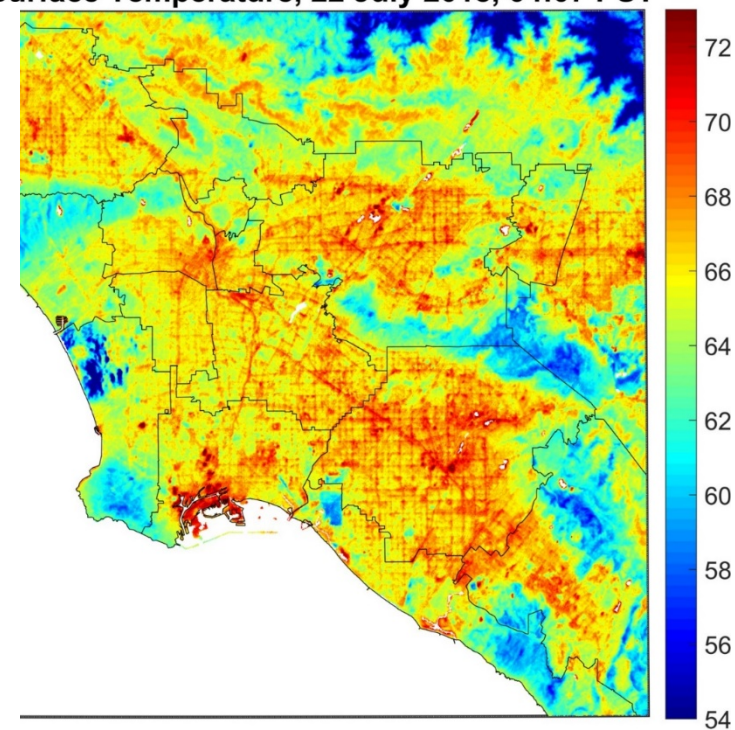
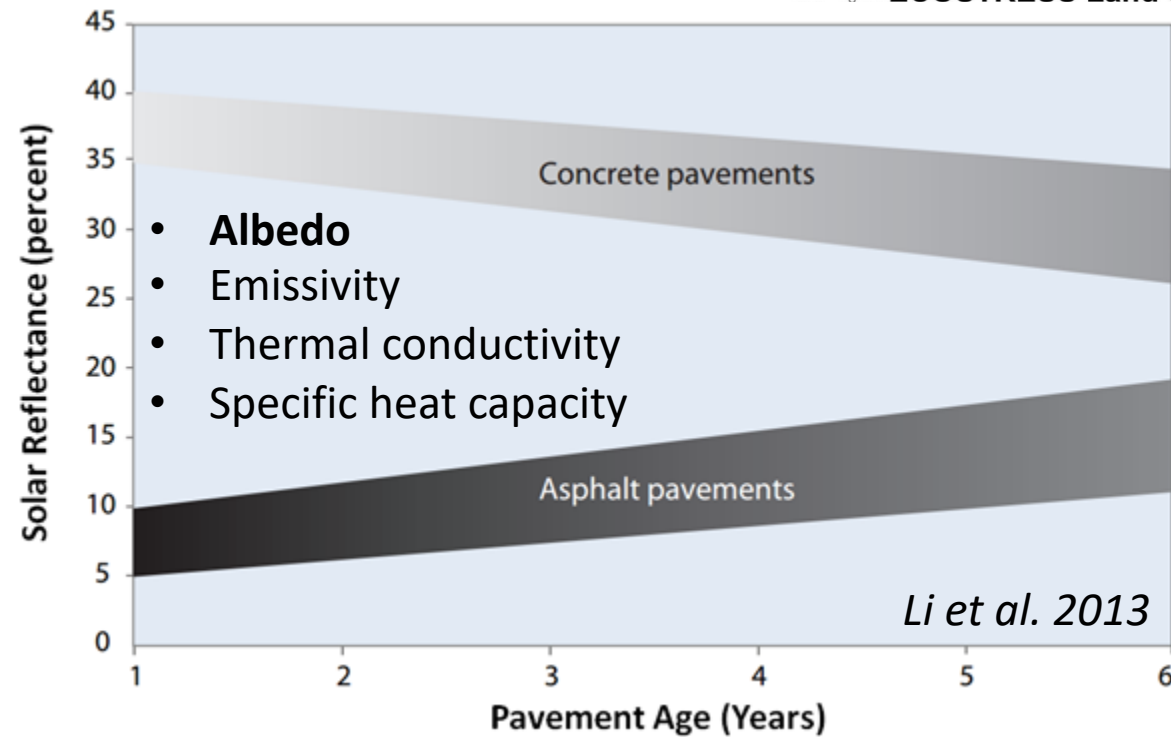


33.5° N

119.0° W

(c) 2018 California Institute of Technology. Government sponsorship acknowledged.

117.6° W



119.0° W

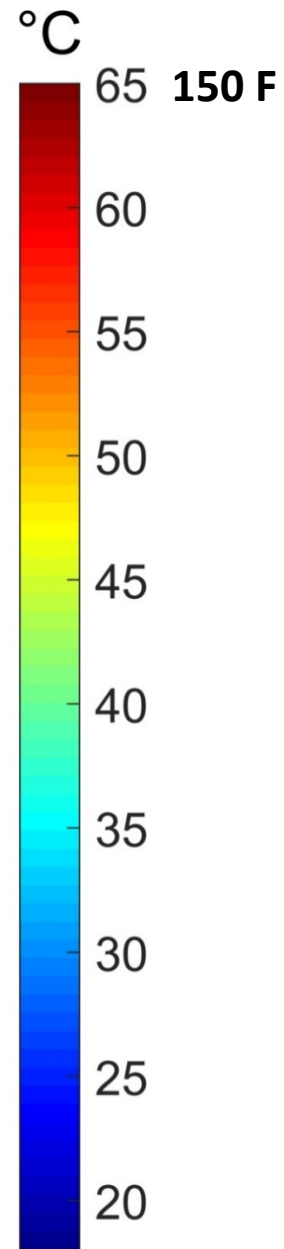
117.6° W

Jordan Av, Gault St to Hart St (1/2 Street)
 Beachy Av, Rangoon St to Reliance St
 Etiwanda Av, Napa St to Malden St
 70th St, 2nd Av to 3rd Av
 Woodbine St, Jasmine Av to Vinton Av
 Carmona St, Clemson St to Bowsfield St
 Orchard Av, 28th St to 29th St
 77th St, Cowan Av to Beland Av
 Coronado St, Berkeley Av to Mayberry St
 Lord St, 90' S/O Marengo St to Pomeroy Av
 President Av, 255th St to 255th St
 Bonnie Brae St, 12th St to 12th Pl
 Selma Av, Laurel Av to Laurel Canyon Bl
 Atoll Av, Barbara Ann St to Gault St
 Superior St, Noble to Lemona

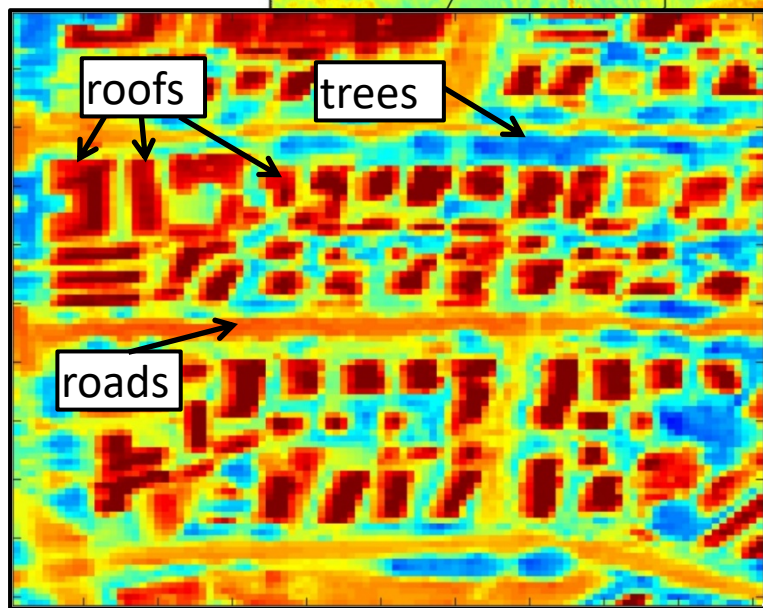


31 July 2018, 03:00 pm PST

34.4° N



HyTES



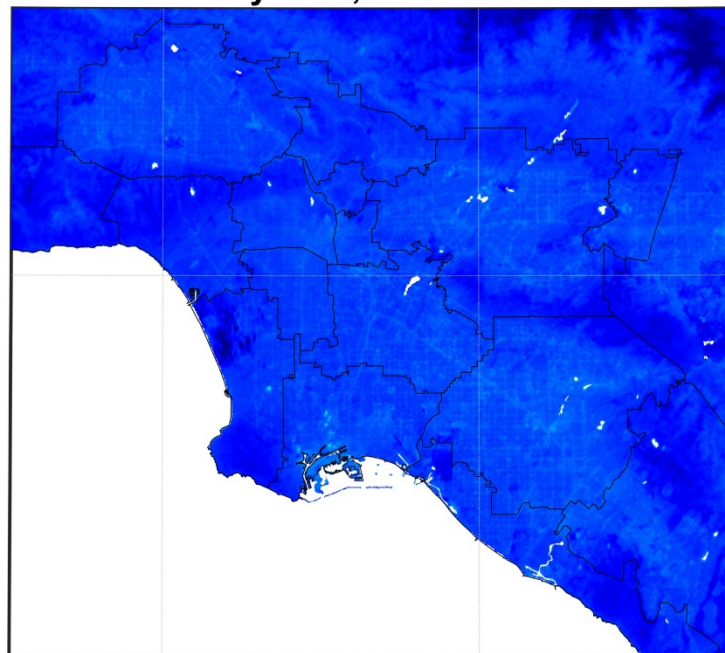
Marine Layer

33.5° N

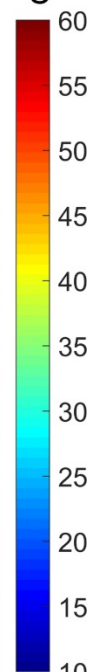
118.7° W

117.6° W

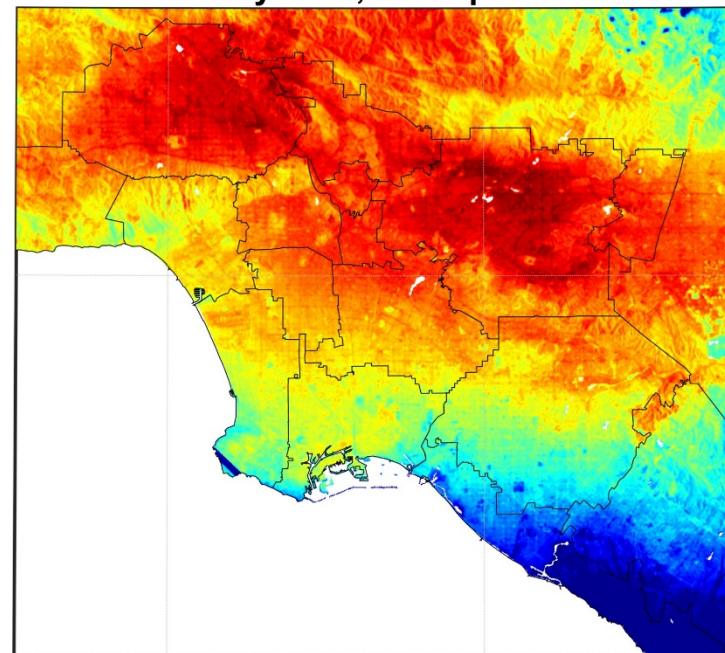
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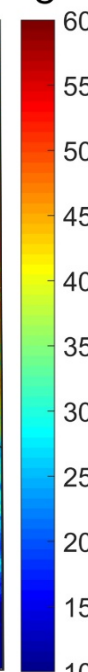
°C



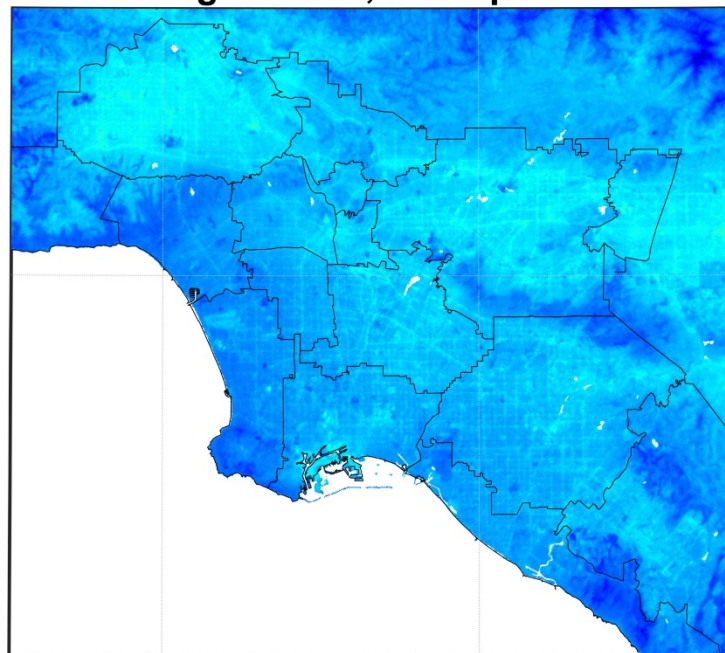
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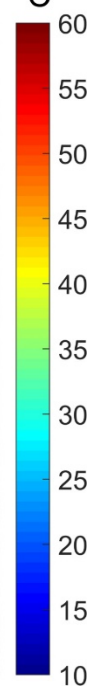
°C



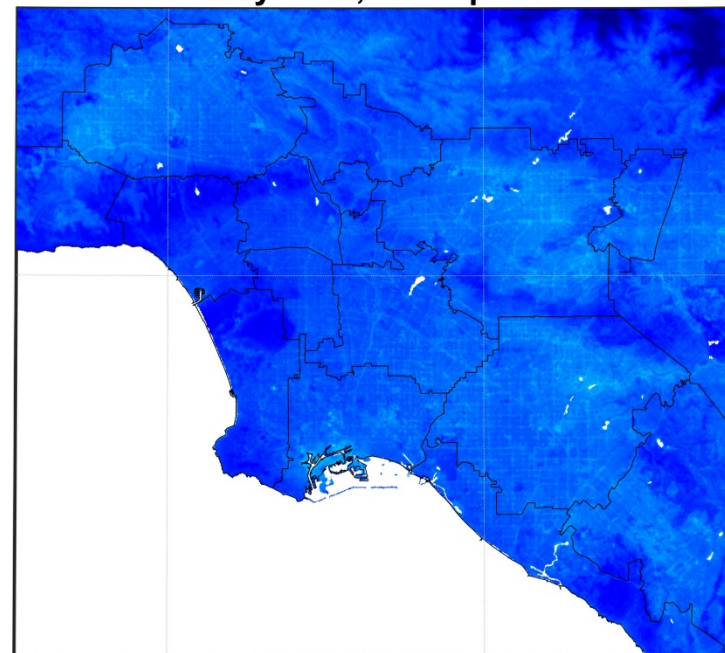
8 August 2018, 09:26 pm PST



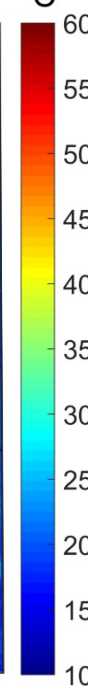
°C



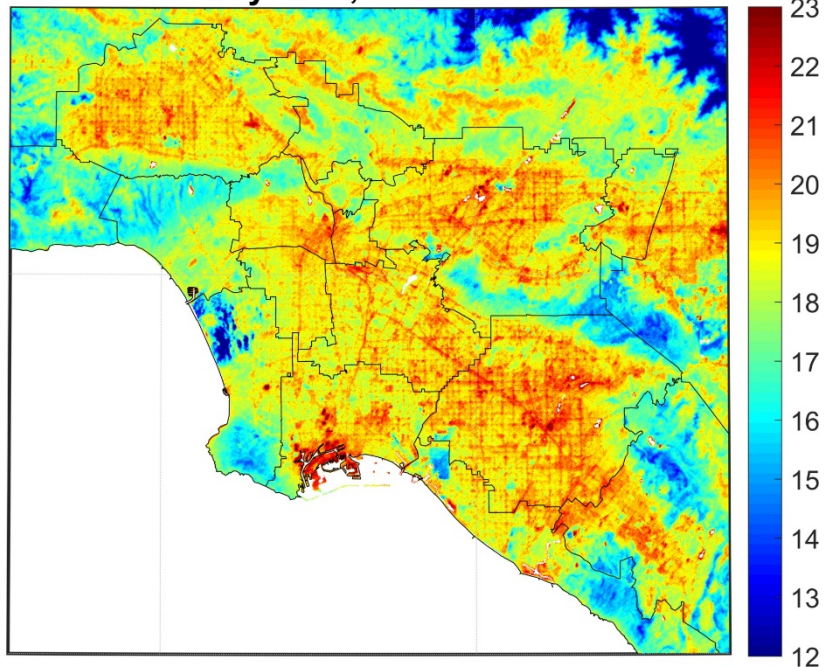
14 July 2018, 11:43 pm PST



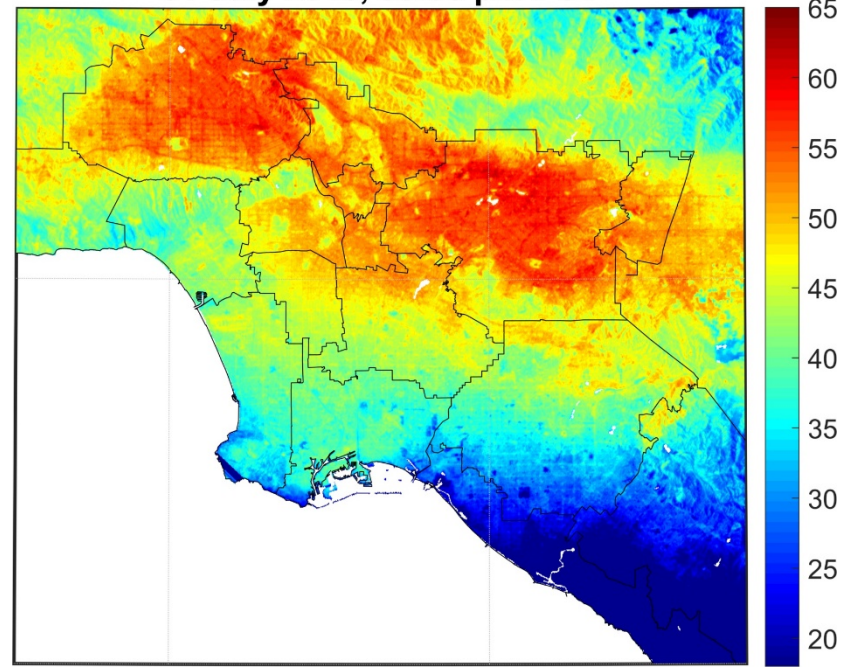
°C



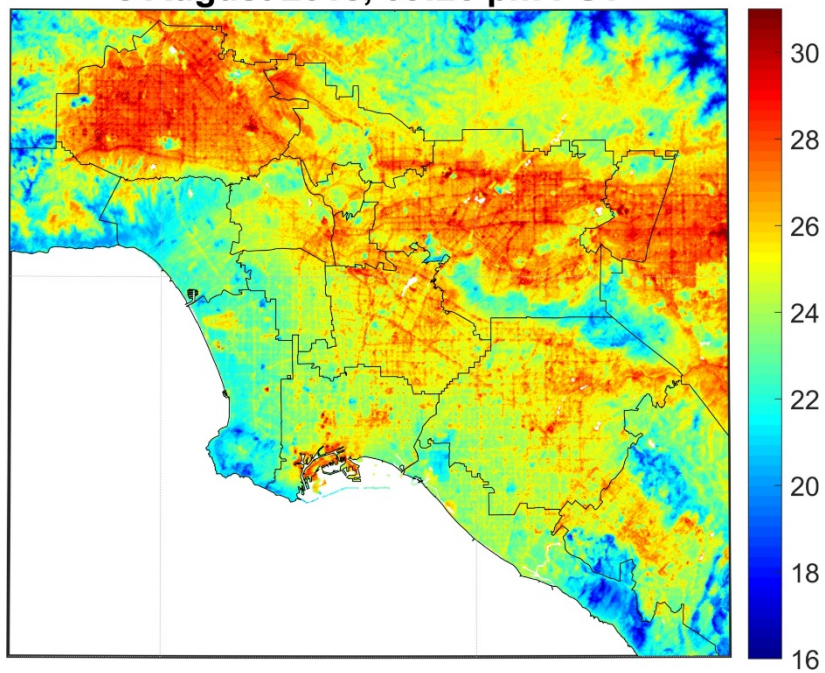
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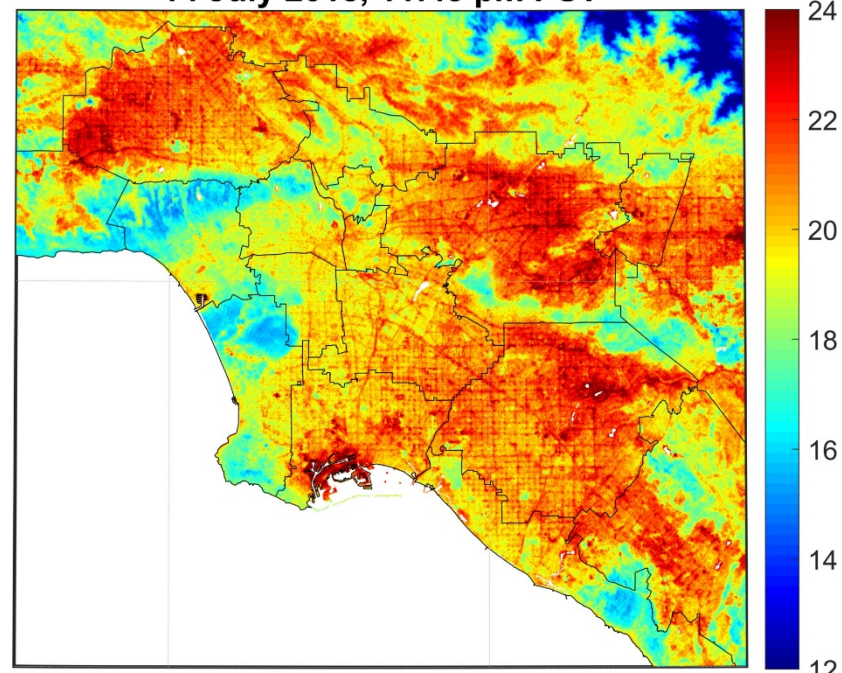
31 July 2018, 03:00 pm PST



8 August 2018, 09:26 pm PST



14 July 2018, 11:43 pm PST



Hottest spot?

150 F

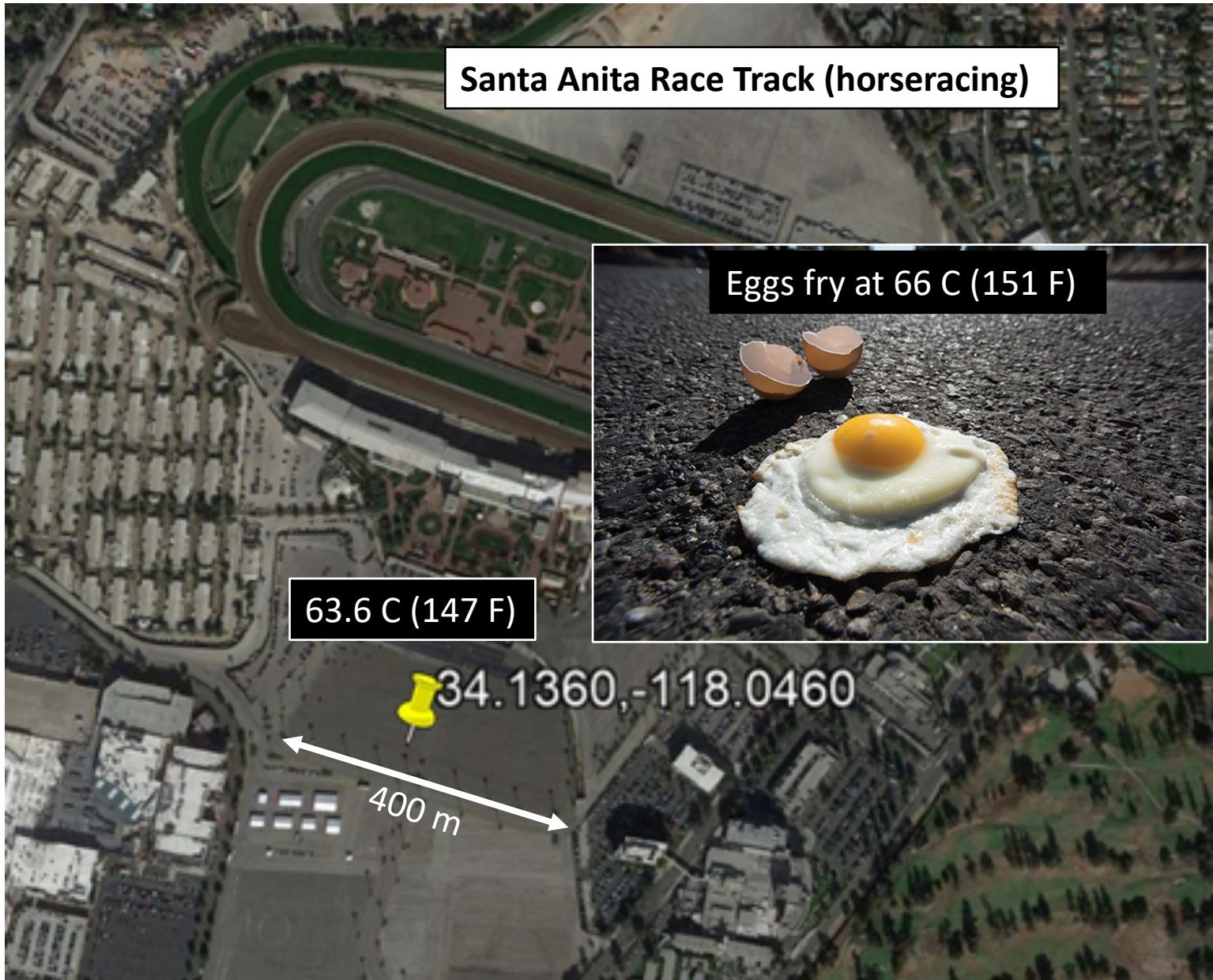
Santa Anita Race Track (horseracing)

Eggs fry at 66 C (151 F)

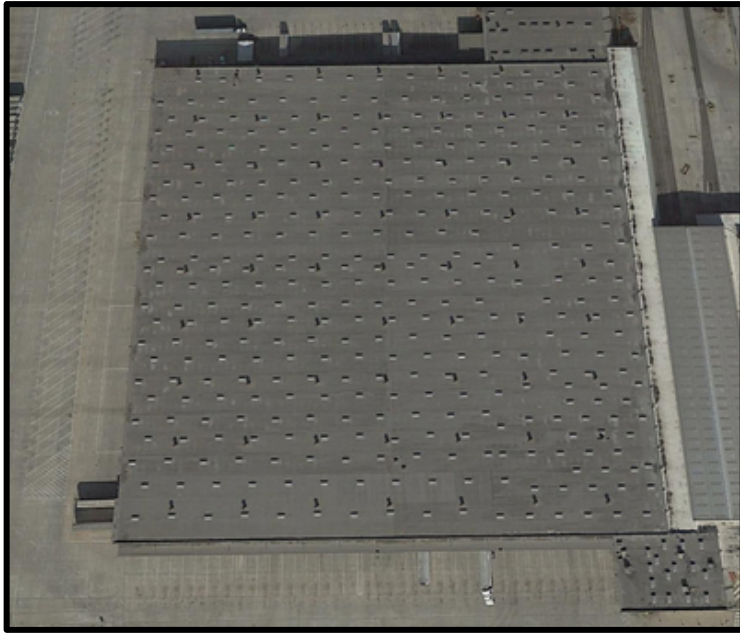
63.6 C (147 F)

34.1360, -118.0460

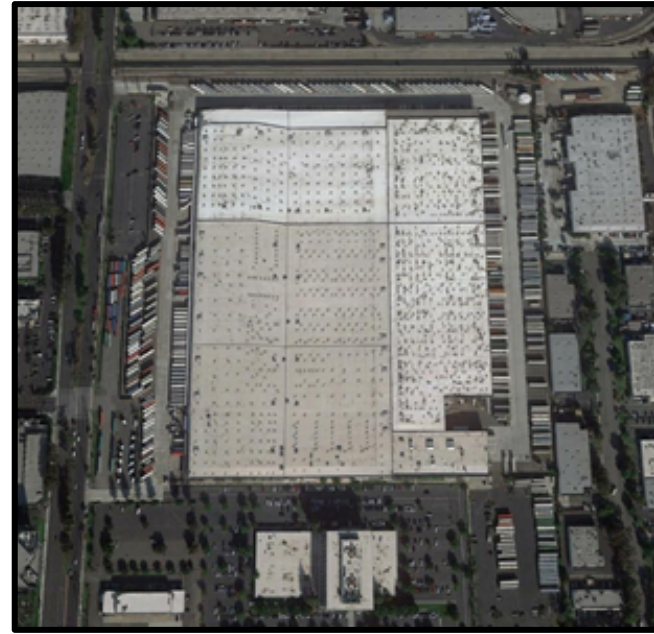
400 m



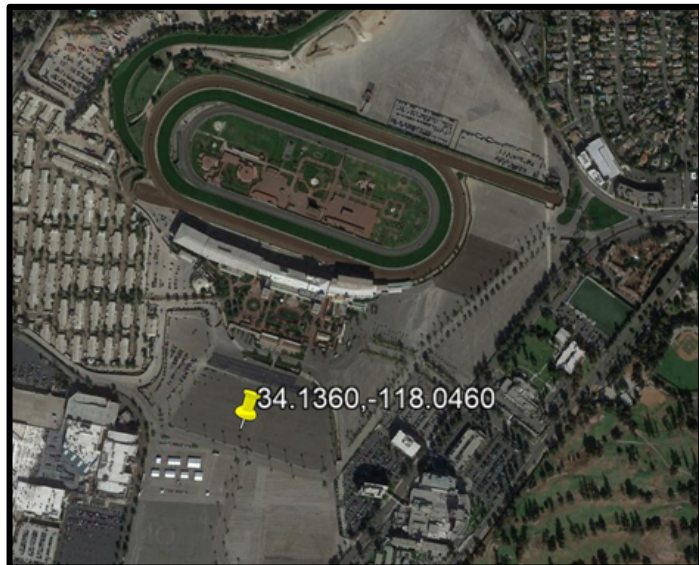
Industrial Black Roof



Industrial White Roof



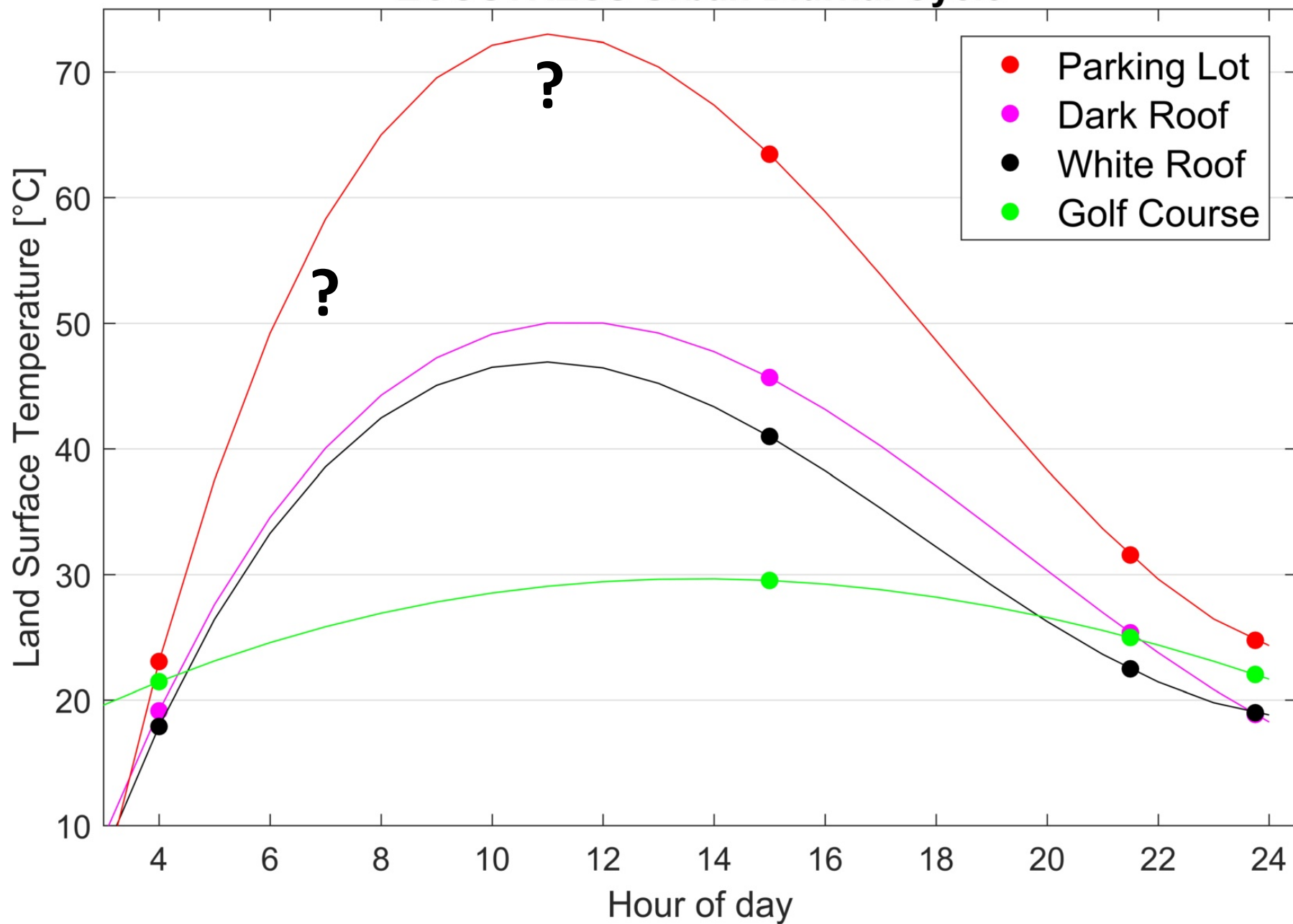
Santa Anita Parking Lot



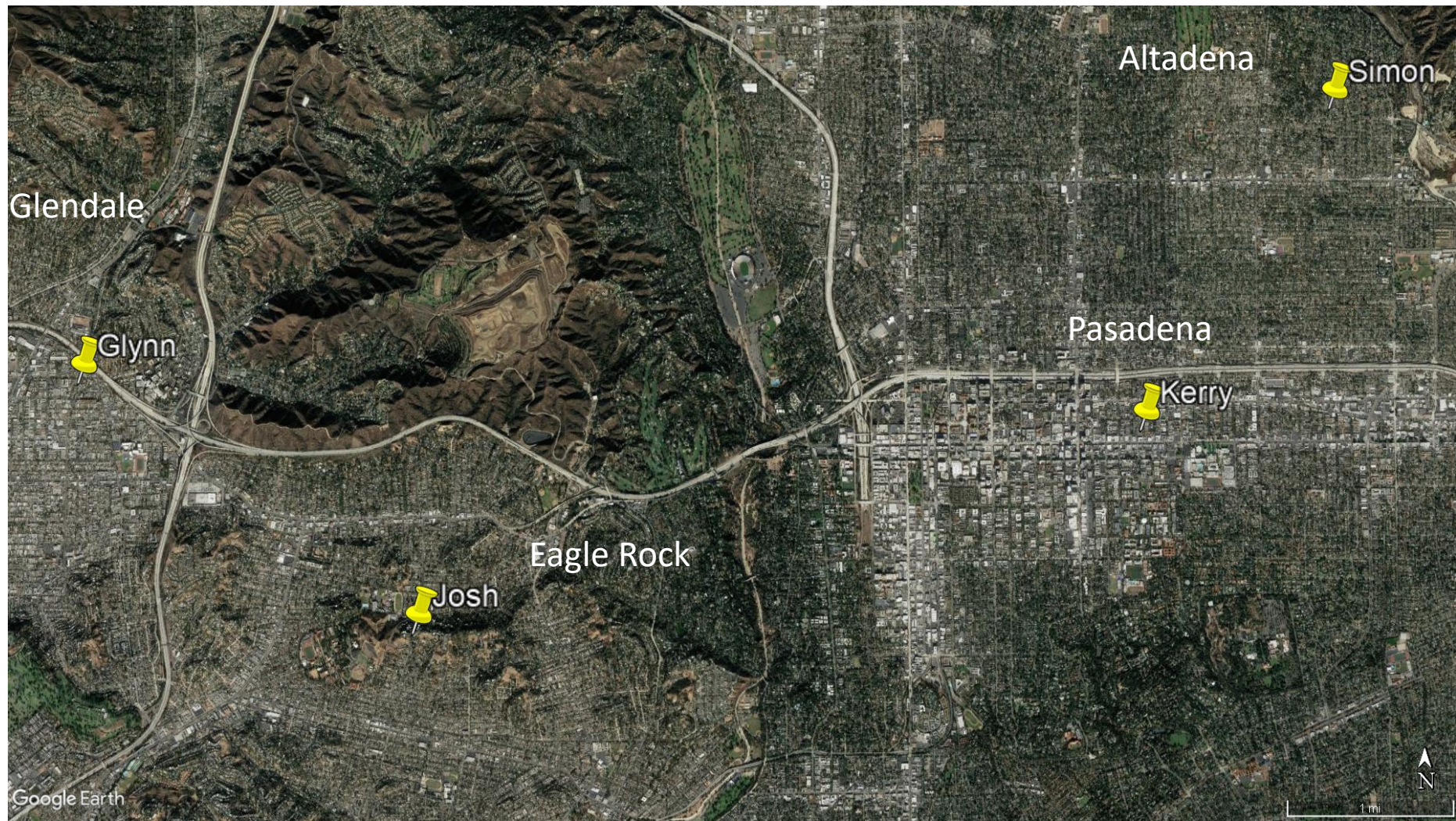
Golf Course



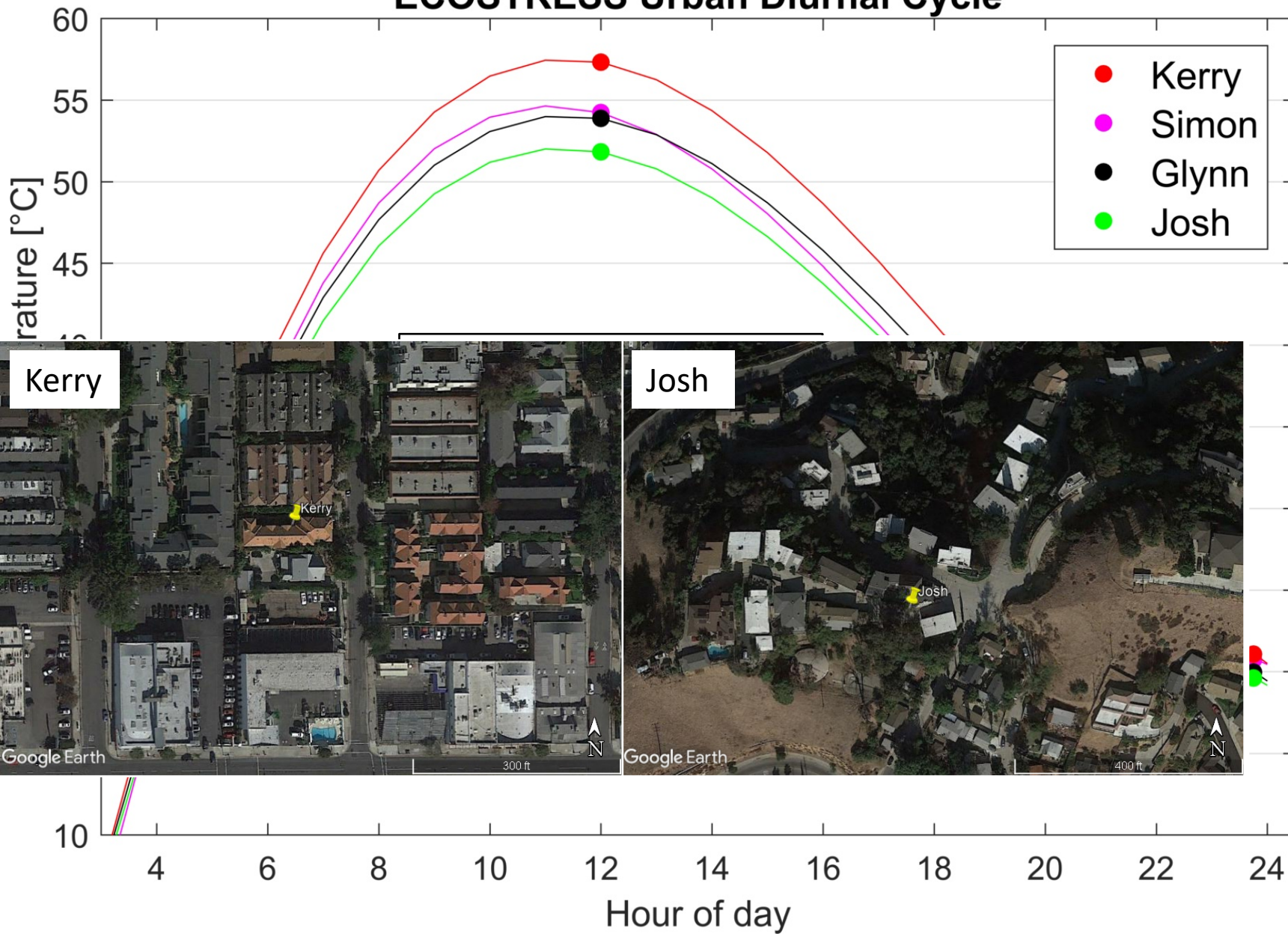
ECOSTRESS Urban Diurnal Cycle



Whose home is the hottest during a heat wave?



ECOSTRESS Urban Diurnal Cycle



Applications

How do we provide tangible benefits to society?



LARC

Los Angeles Regional Collaborative
for Climate Action and Sustainability




Heat Vulnerability Index (HVI) Model

$$HVI = E_i(x) + S_i(y) - R_i(z)$$

$E_i(x)$ **Exposure**
 $x = \text{Land Surface Temperature (LST)} \longrightarrow \text{ECOSTRESS}$

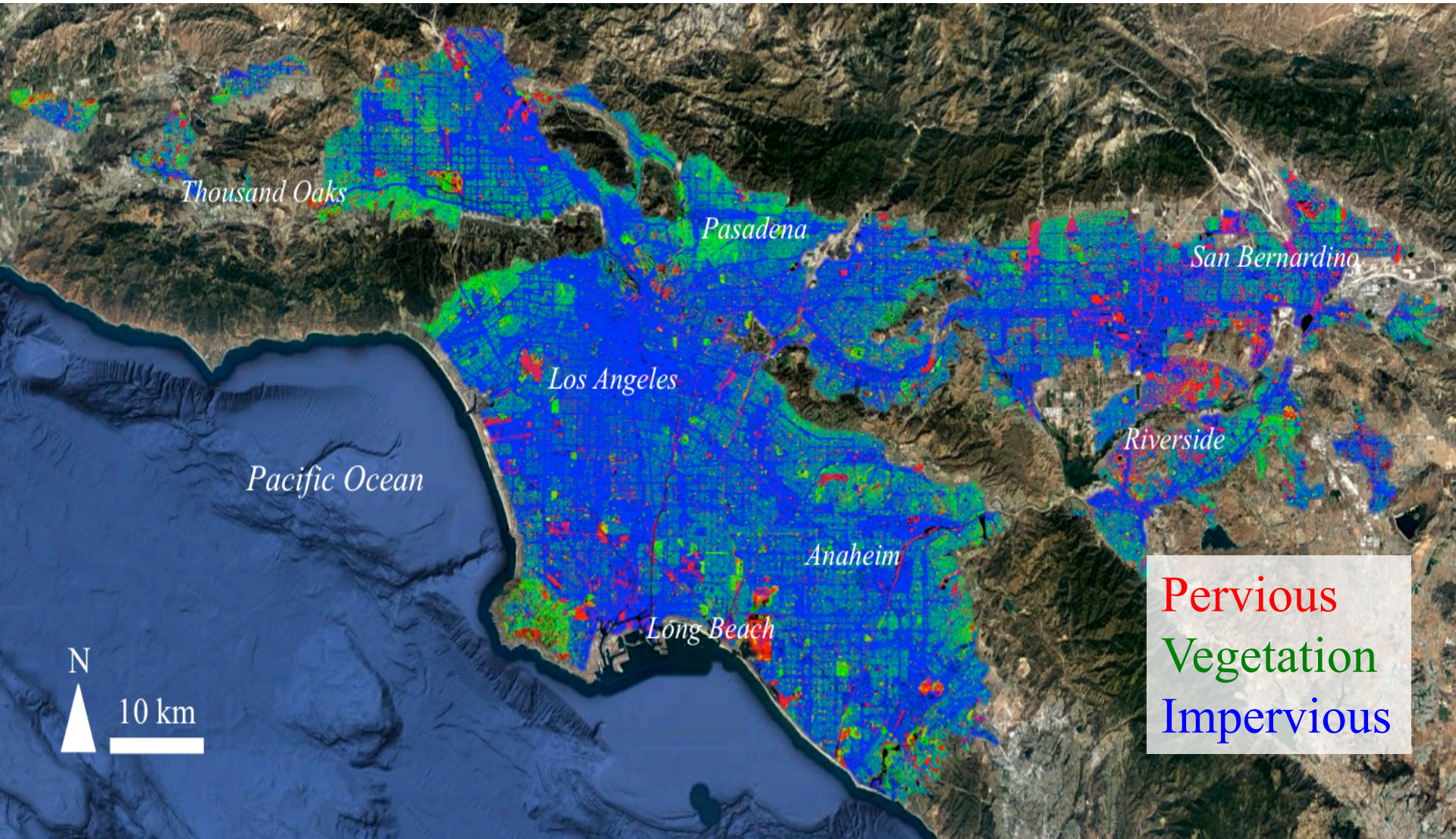
$S_i(y)$ **Sensitivity**
 $y = \text{Socio-Demographic Data (poverty, elderly etc)}$
(source: SEDAC, 200m)



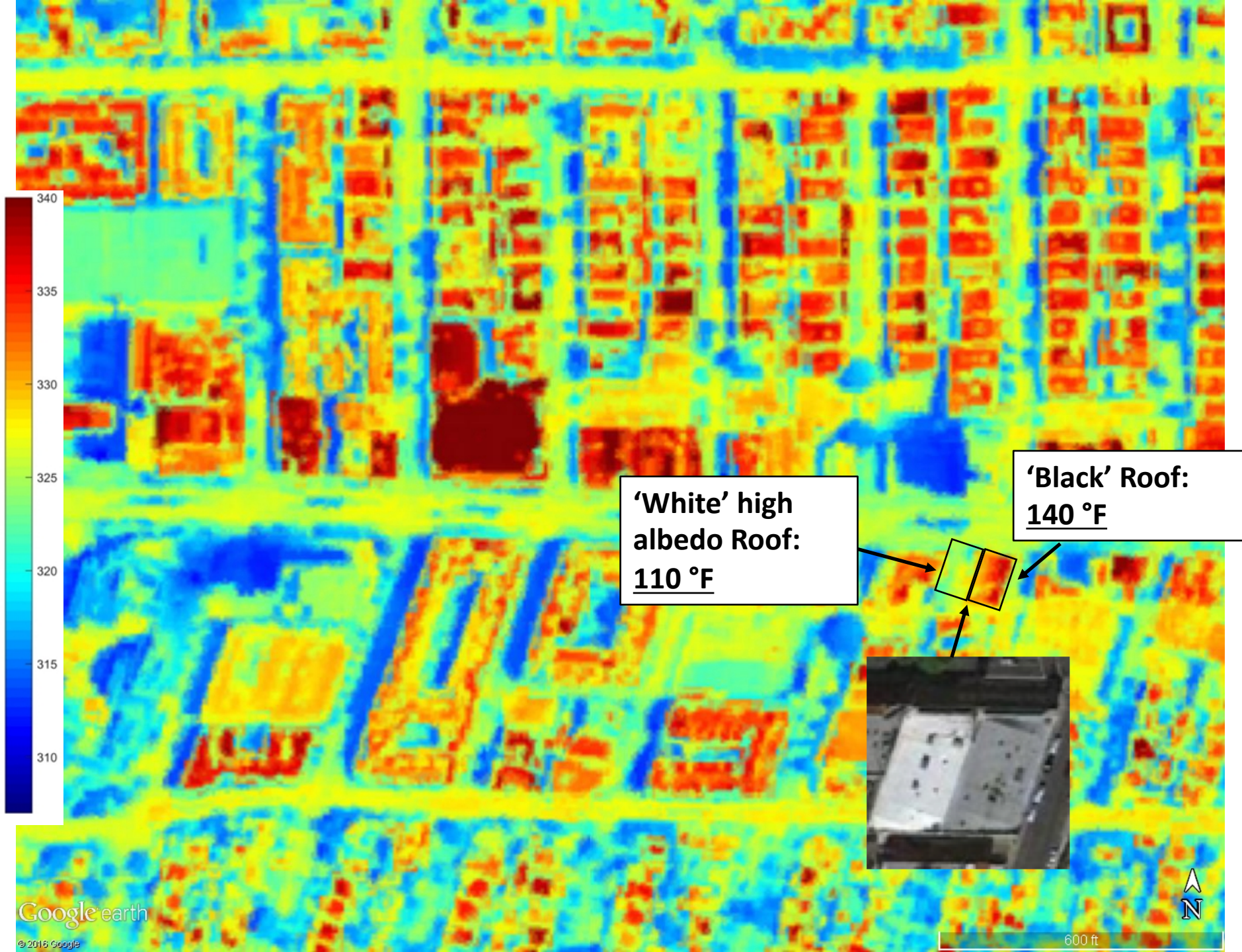
SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)
A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIESIS at Columbia University

$R_i(z)$ **Resilience**
 $z = \text{Vegetation fraction, Annual Income, Education}$
Still to include: Albedo, Building height, ET

Wetherley, Erin B., Joseph P. McFadden, and Dar A. Roberts. 2018. “Megacity-Scale Analysis of Urban Vegetation Temperatures.”, RSE, 2018



Study Area = 4,466 km²



Principal Component Analysis (PCA)

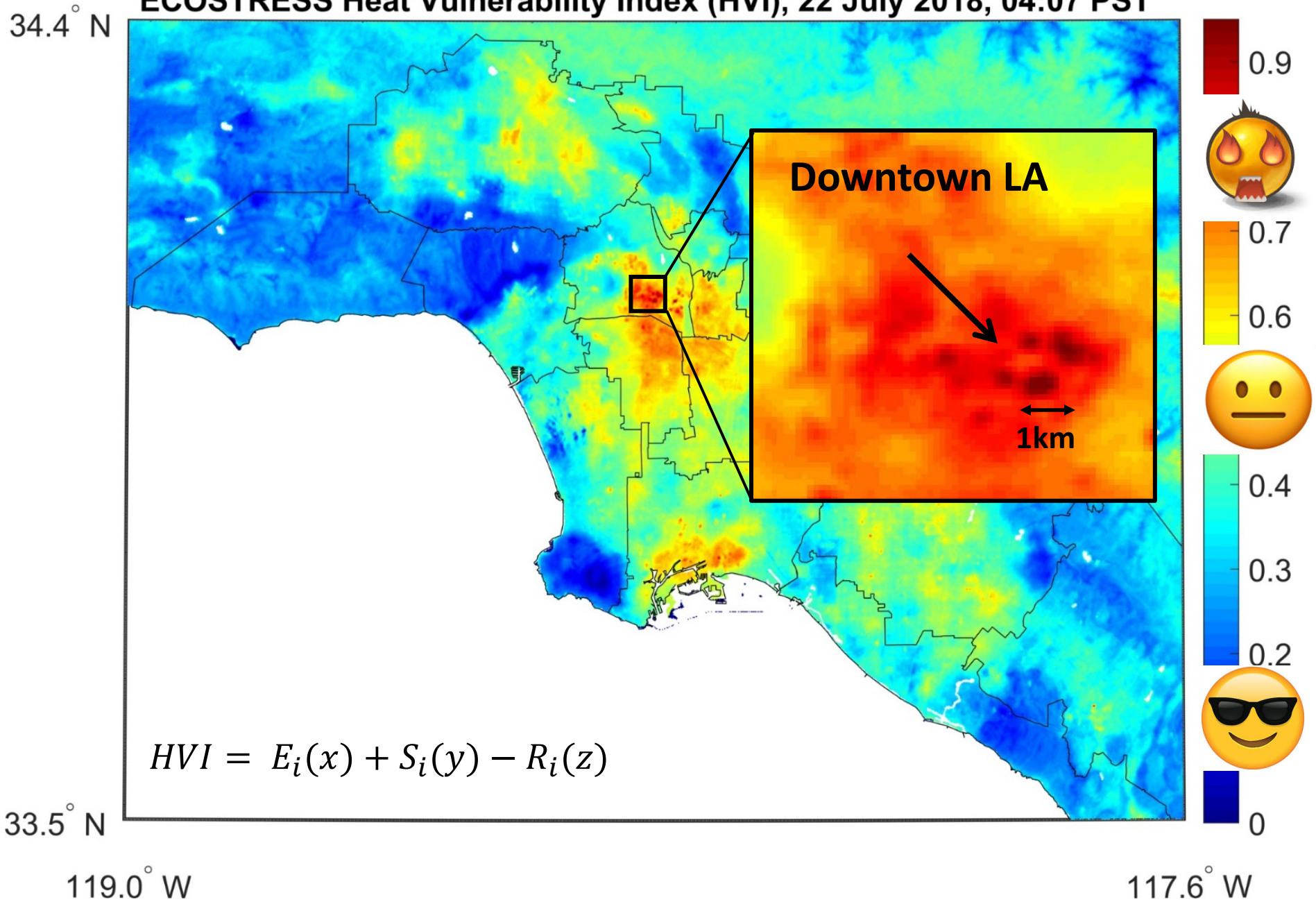
Socio-demographic variables

Demographic Variables	PC1	PC2	PC3
	Sensitivity 1	Resilience	Sensitivity 2
Year Housing Built	0.41	0.24	-0.00
Poverty Level	0.51	-0.23	0.00
Disabled Population	0.40	0.10	0.06
Unemployment	0.43	0.06	0.00
Elderly Population	-0.1	0.02	0.65
Population Density	0.17	-0.17	0.44
Income	0.23	0.48	-0.08
Education	0.14	0.51	-0.00
Vegetation Index Fraction	-0.33	0.58	0.07


 AVIRIS vegetation fraction – Wetherley et al. 2017

Hulley and Shivers, 2018

ECOSTRESS Heat Vulnerability Index (HVI), 22 July 2018, 04:07 PST

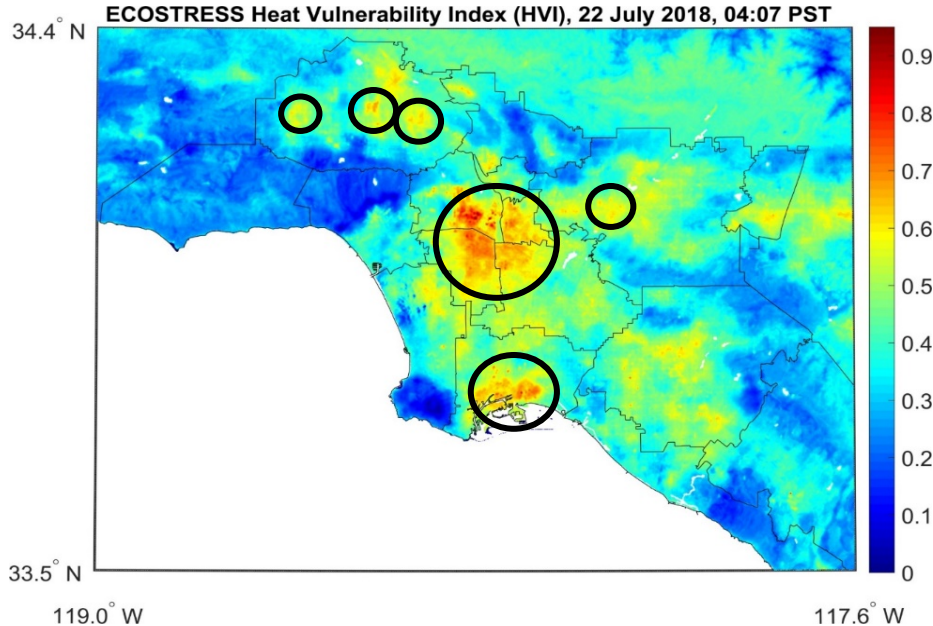




Heat advisories and public health.

Provide HVI to issue near real-time heat advisories targeted to vulnerable regions in Los Angeles

Identify optimal locations for cooling centers



Use HVI to advise on realistic health advisories (currently use Heat Index from NWS)

2018 Health Advisories		
Date of Release	Title	
August 01	Air Quality Advisory: Air is unhealthy in Santa Clarita Valley	View
July 30	Air Quality Advisory: Air is unhealthy in Antelope Valley and Santa Clarita Valley	View
July 30	Heat Alert: High temperatures forecast for Pomona area and San Fernando Valley	View
July 29	Air Quality Advisory: Air is unhealthy in parts of LA County	View
July 28	Air Quality Advisory: Air Quality is unhealthy in parts of LA County	View
July 27	Air Quality Advisory: Air is unhealthy in parts of LA County	View
July 26	Air Quality Advisory: Air is unhealthy in parts of LA County	View

Science Traceability for Heat Vulnerability and Human Health

H-4d. Understand linkages between anthropogenic modification of the land, including fire suppression, land use, and urbanization on frequency of and response to hazards. This is tightly linked to H2a, H2b, H4a, H4b, H4, and H4d.

Category	Descriptor
Partner's current data set / info products	Air temperature (F) Heat Index (0-1)
Geographic Domain	City or County Level
Spatial Resolution	TBC what the resolution is on the temp and heat index grids
Temporal Frequency	~Daily
Partner's existing data formats	Maps of weather forecasts (interpolated across region) Excel tables
How is the data being used currently?	<ul style="list-style-type: none"> • Emergency response and cooling centers (hours, location) • Targeted health advisories
Your work/proposed products	<ul style="list-style-type: none"> • Land surface temperature (F) • Heat Vulnerability Index (0-1)
Complementary	<ul style="list-style-type: none"> • Product temporal repeat is every 4 days, but expected higher spatial • Heat Index that incorporates neighborhood-specific information (demographics)
Potential Joint Activities/Studies with Partner	<ul style="list-style-type: none"> • Retrospective analysis of current heat index with proposed heat index, plus impacts on resource deployment, advisories • Shared datasets for hospital surveillance for heat-related treatments • Studies of how well cooling tech and interventions is working (cool pavements, roofs, vegetation).
Example Objective	<ul style="list-style-type: none"> • Determine utility of HVI versus the standard Heat Index for assessing heat wave impacts in X County.
Example Hypothesis	<ul style="list-style-type: none"> • HVI is better correlated with heat-related stress conditions reported at hospitals.
More examples of science qs and objectives on next page, with an SATM	

SATM Example

Science / Applied Science Question	Science / Applied Science Objective(s)	Partners	Partner Data Baseline	Physical Parameters	Observables	Requirements	Anticipated / Desired Capability	Mission Functional Requirements	DS Reference
What area within an urban region are most impacted or vulnerable to heat stress?	AS-I. Determine areas with highest rates of intensity of heat stress / urban heat island for XXXX dates.	Public Health County Water and Power Utilities	X weather stations in ABC County. Historical daily weather station data, minimal geospatial datasets. ?	Optimally, LST with uncertainty XYZ, with spatial ABC resolution and DEF temporal resolution for GHI years.	Optimally, LST with uncertainty XYZ, with spatial ABC resolution and DEF temporal resolution for GHI years.	pixel size, swath width, wavelength range, dynamic range, NEDT at sensor		Need to have coverage of LA County Region. -- LAC Region is in the XYZ orbit.	W-2, W-3
	AS-II Identify neighbor-by-neighborhood resiliency to impacts of urban heat stress.	Public Health County Water and Power Utilities		Spatial Resolution, Temporal Resolution, Spatial Coverage, Uncertainty	Spatial Resolution, Temporal Resolution, Spatial Coverage, Uncertainty			Heat wave info is determined daily by X weather stations. XYZ instrument will fill spatial gaps on days data are available.	
	AS-III. Provide urban heat island and vulernability climatology data over 15 years to inform long term planning metrics to mitigate impacts of heat stress	City or County Planning			Urban vegetation (?)				

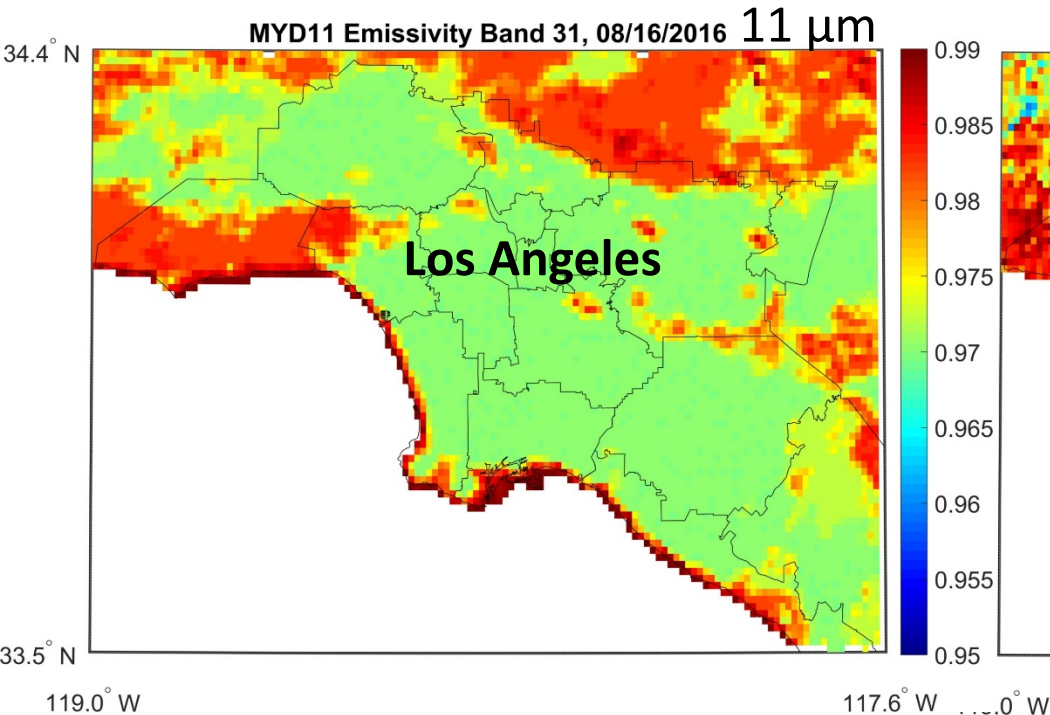


Questions?

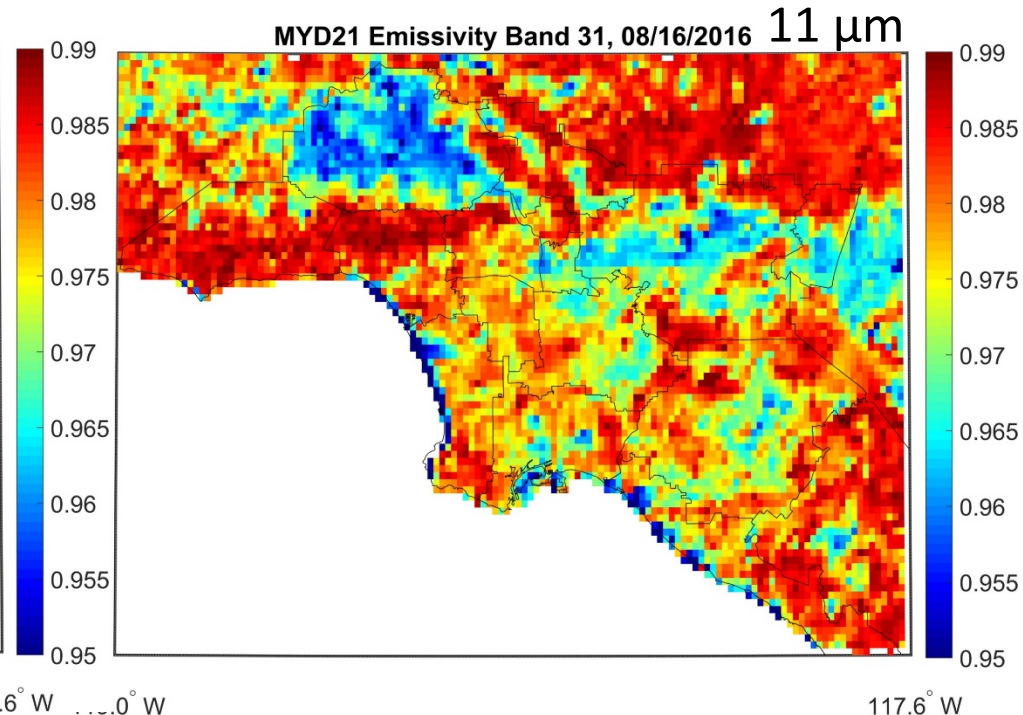
glynn.hulley@jpl.nasa.gov

Urban Emissivity Variation

MxD11 Classification

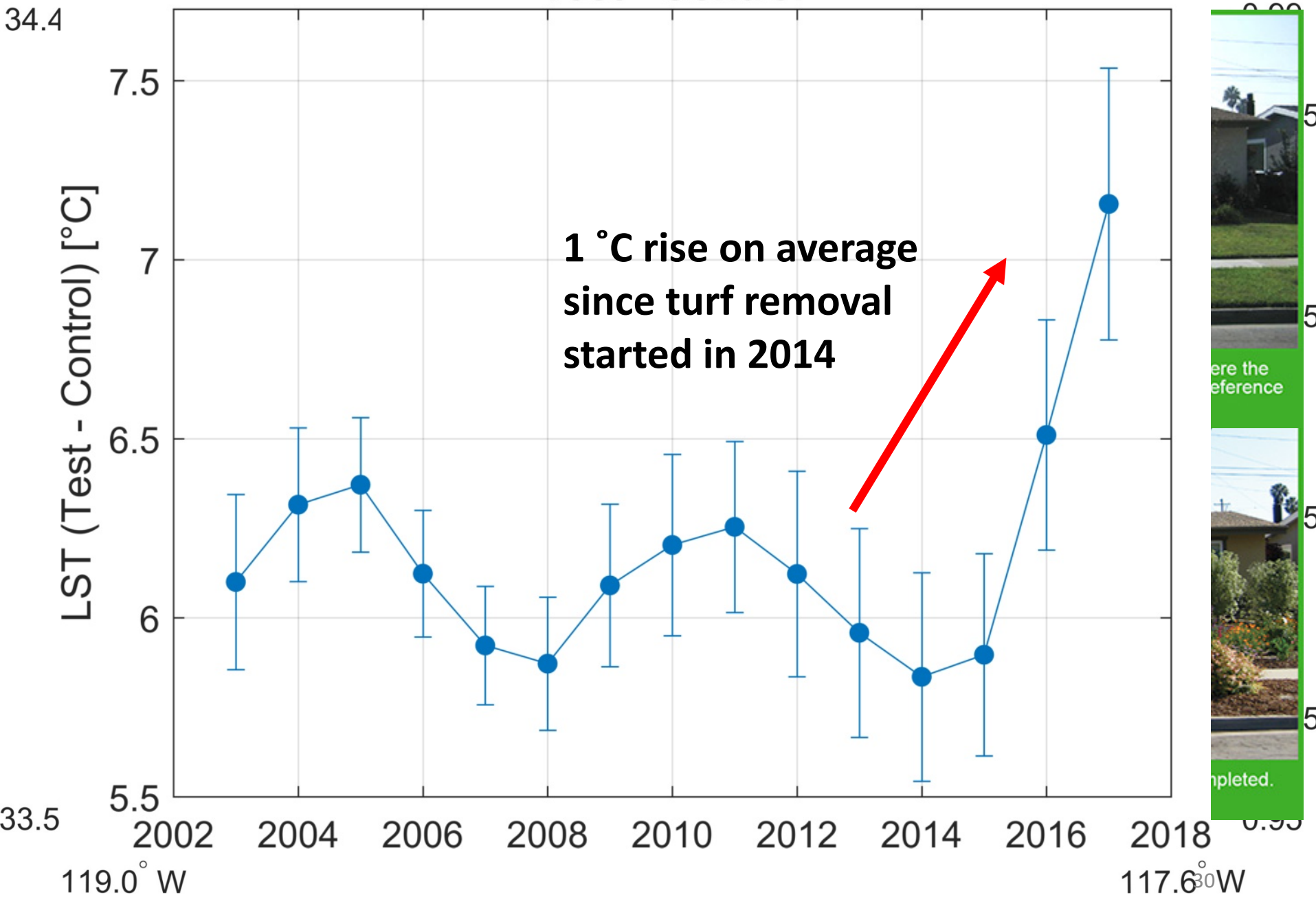


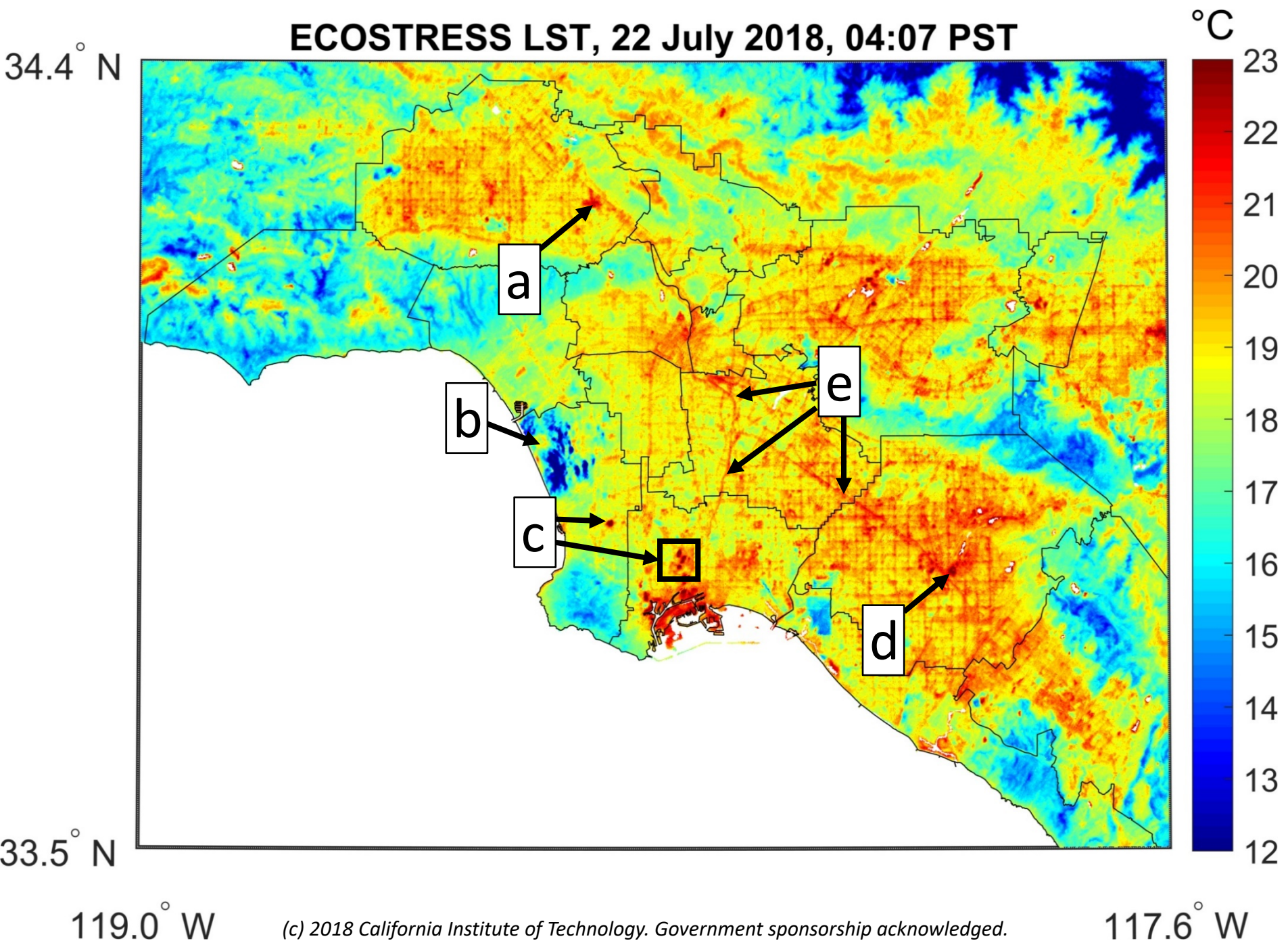
MxD21 TES

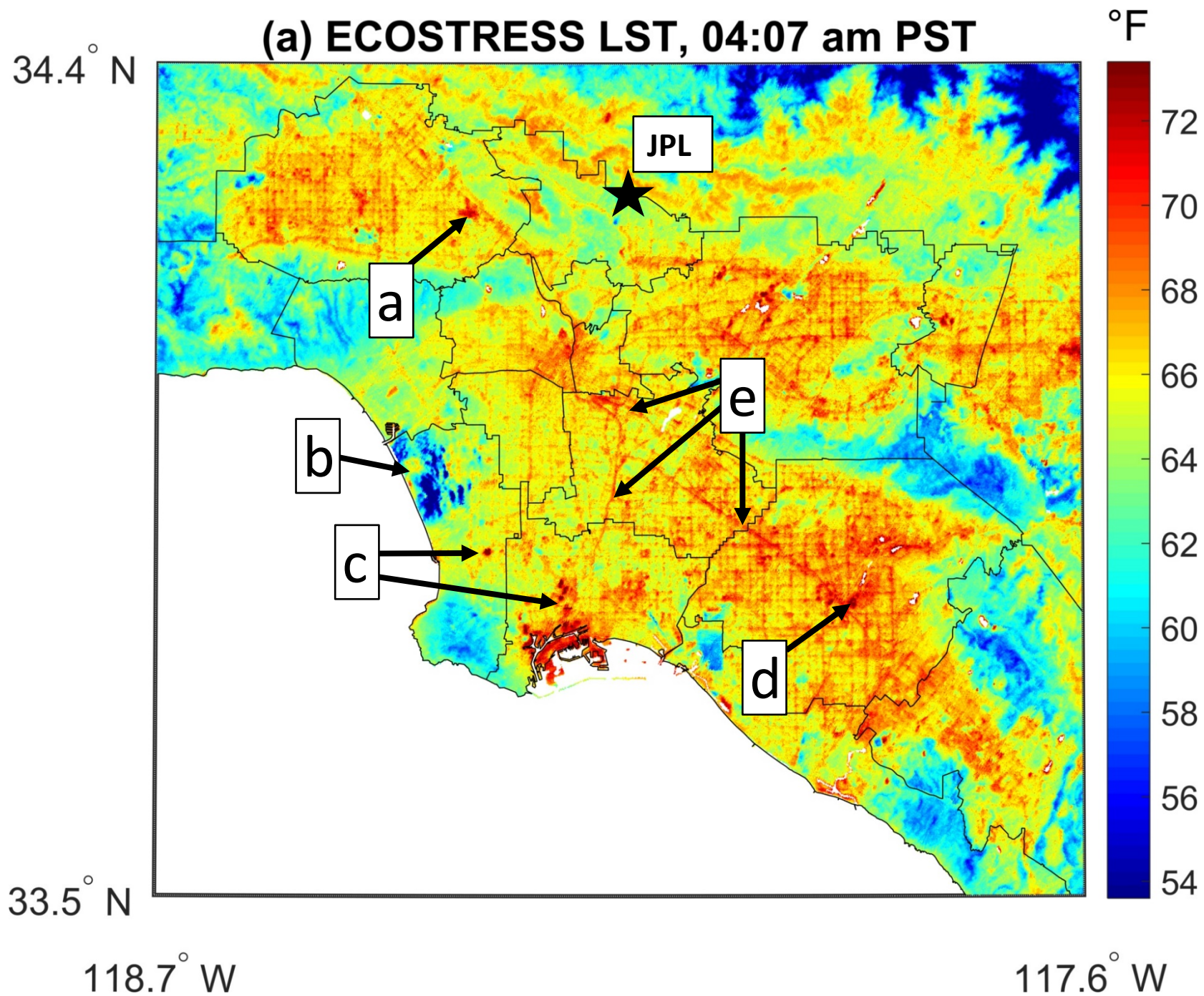


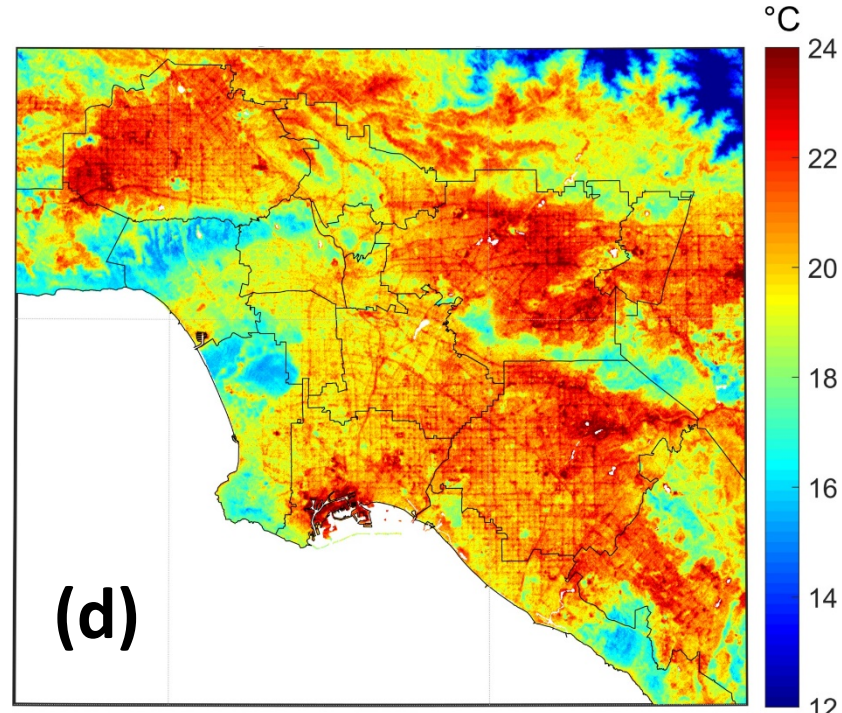
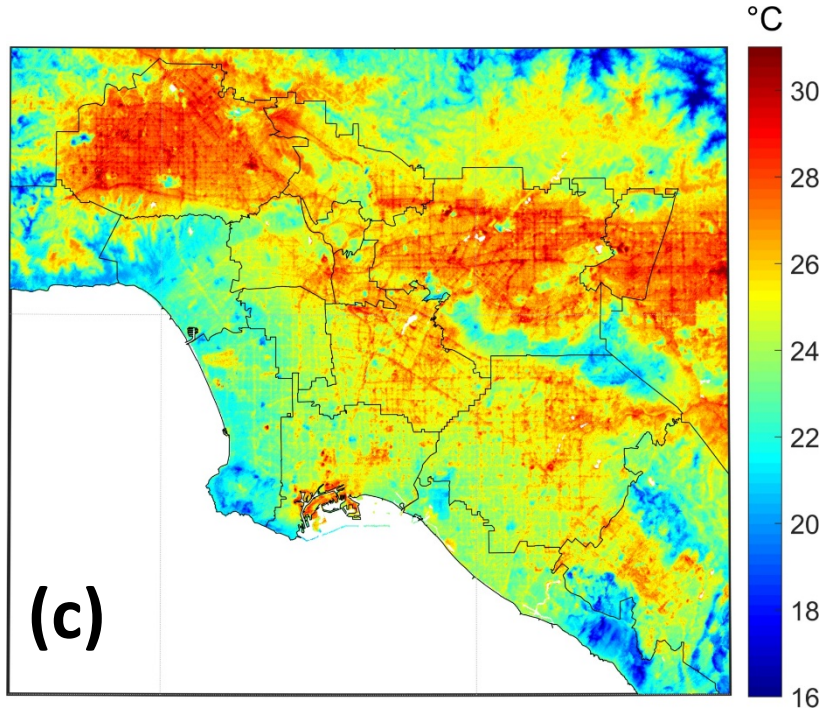
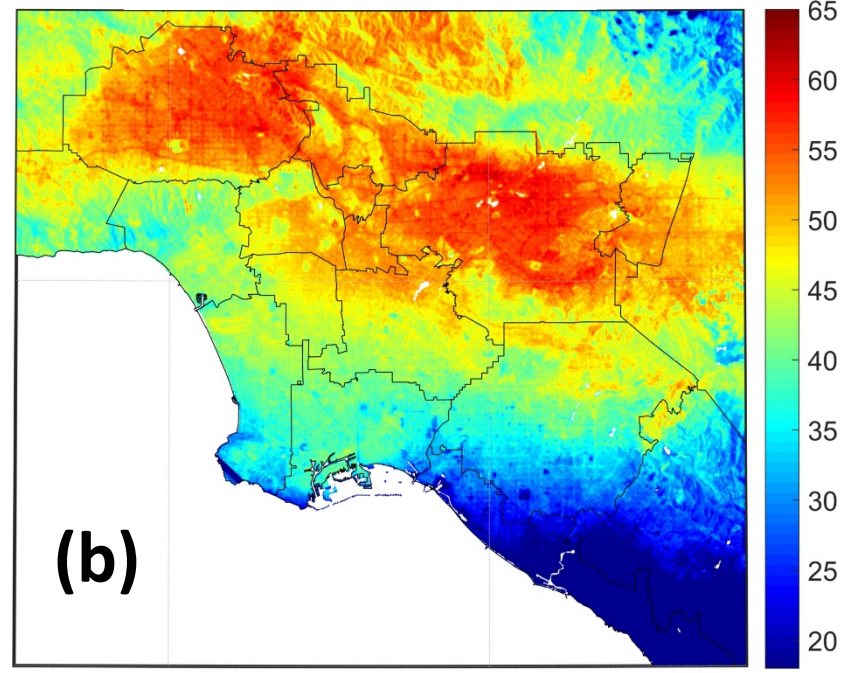
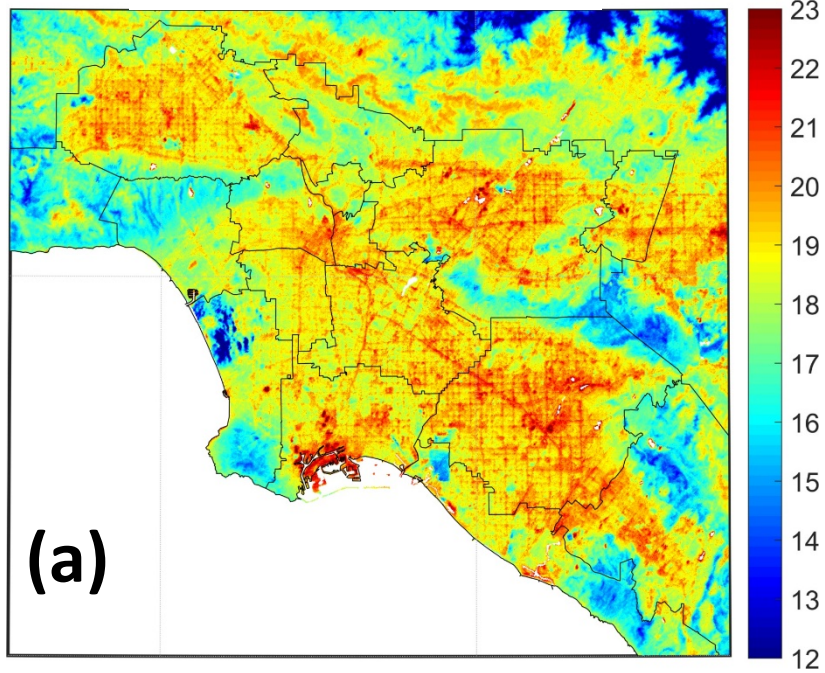
- Split-window approaches, e.g. MYD11 assume fixed emissivity over different land classes, e.g. Urban emissivity = 0.97 (green)
- TES approaches, e.g. MYD21 physically retrieve the emissivity state of surface

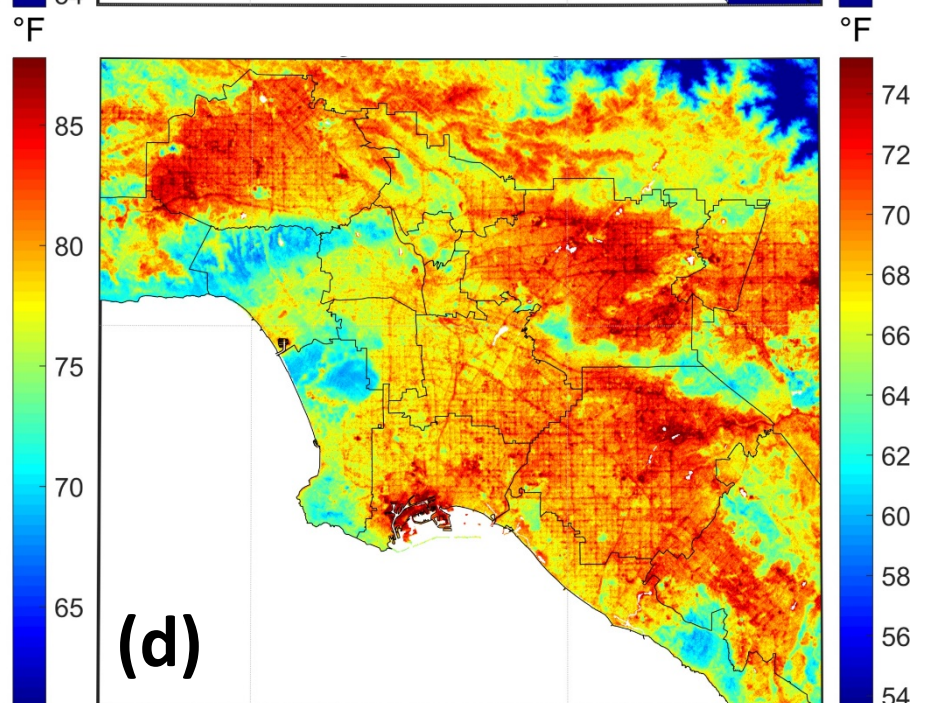
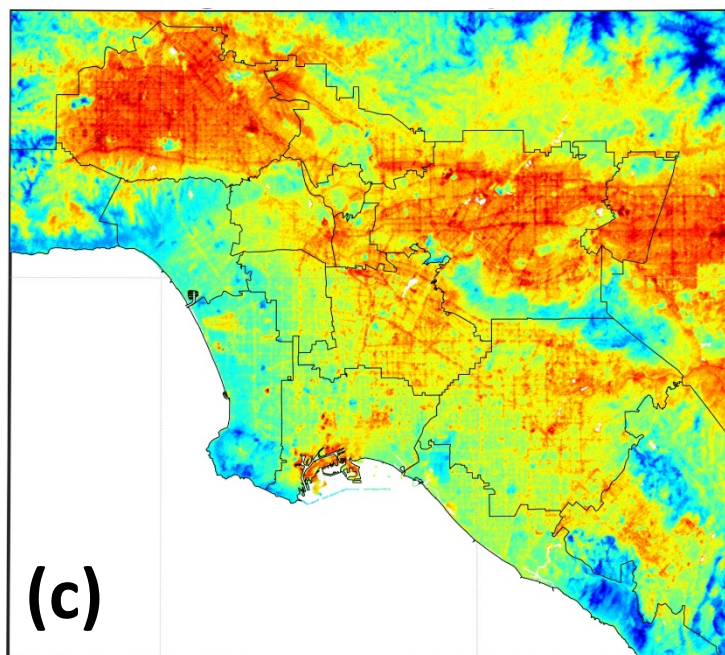
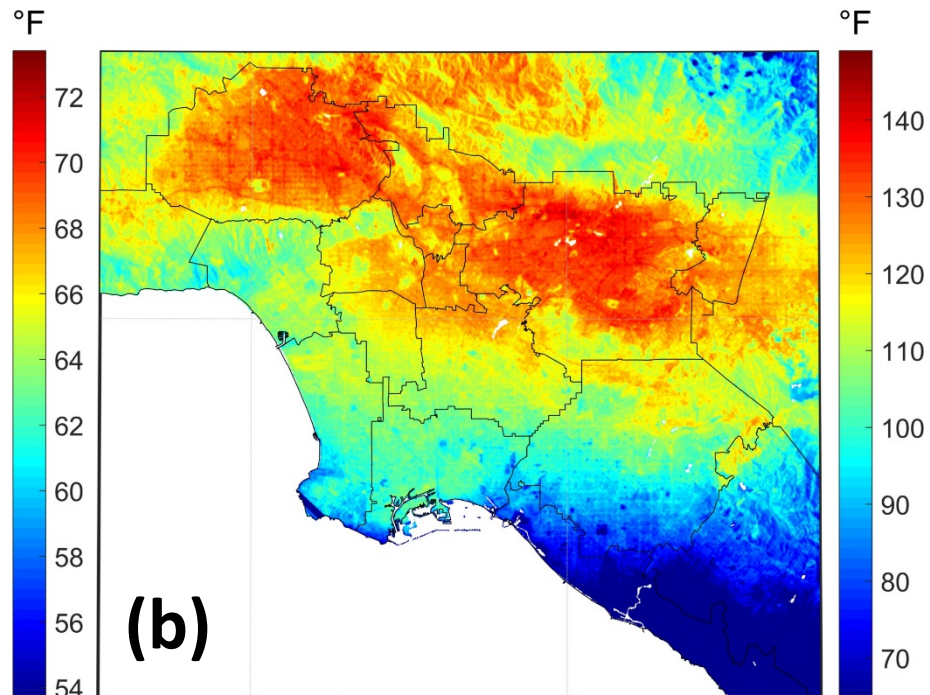
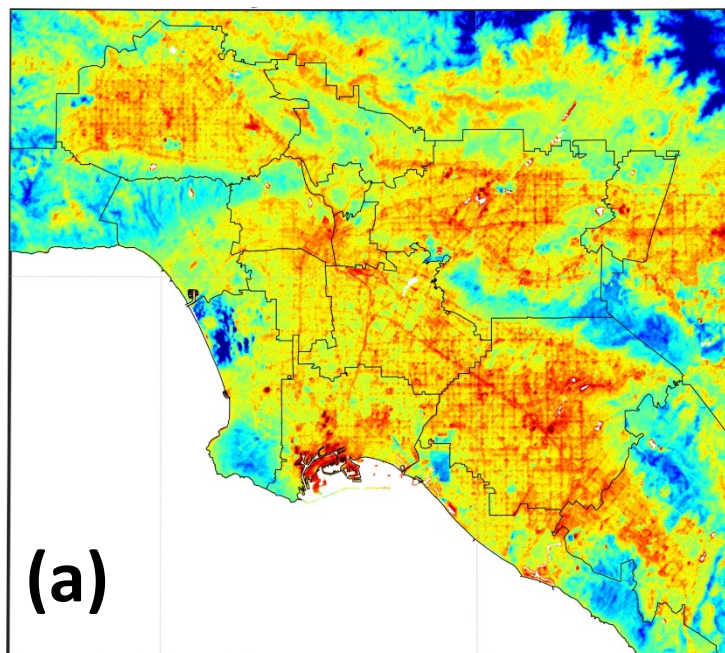
Test - Control





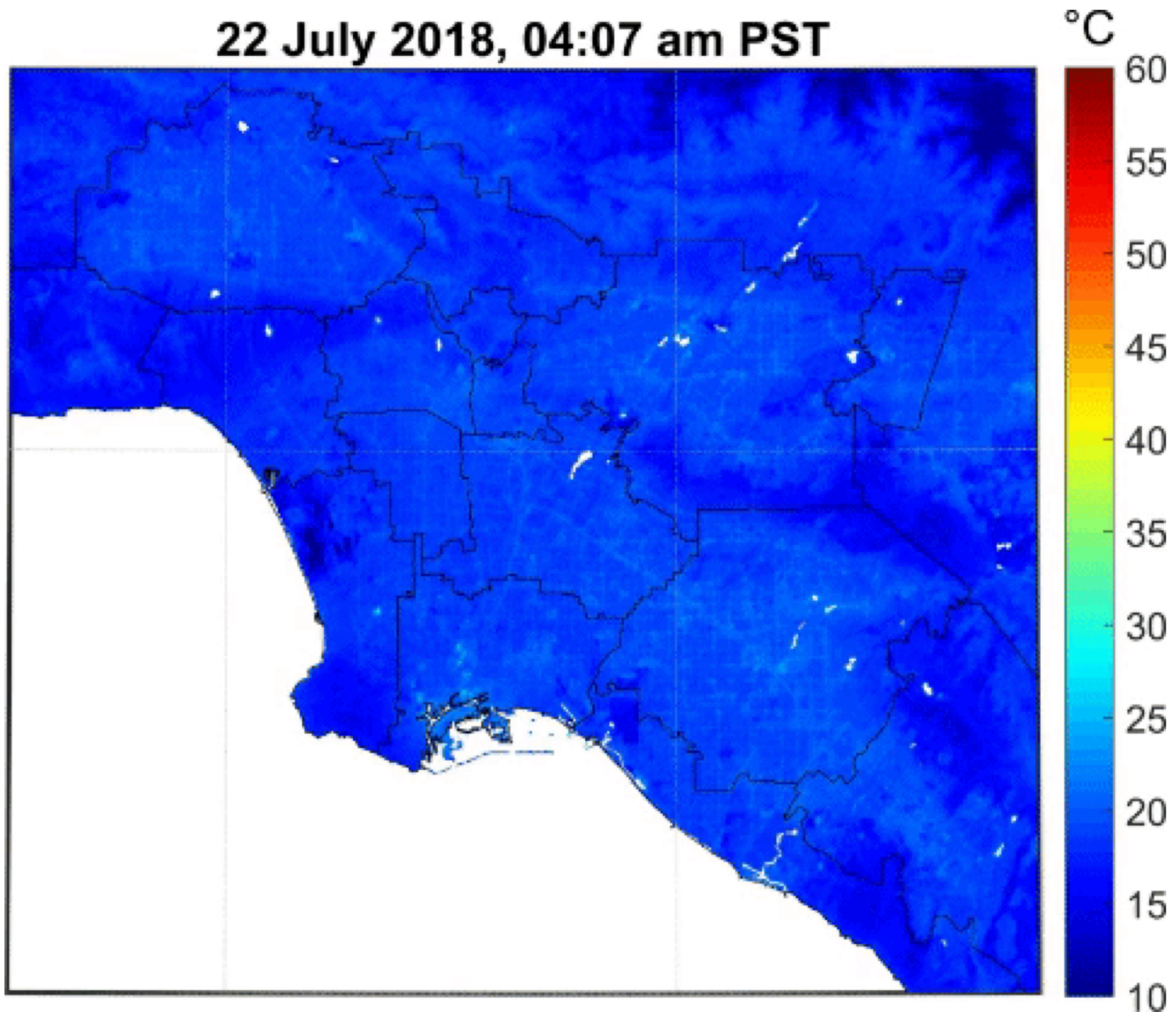






**“Tracking the pulse/temperature of Los Angeles”
“Understanding how large cities breath”**

22 July 2018, 04:07 am PST



ECOSTRESS Land Surface Temperature [K], 22 July 2018

